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Upper Thompson Sanitation District

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Estes Park, CO

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16. ABSTRACT

The Upper Thompson Sanitation District (UTSD) advanced wastewater treatment facility, located in Estes Park, Colorado, incorporated several unique unit processes. Among these were flow equalization, attached growth nitrification, mixed media filtration and ozone disinfection. Plant design flow was 5,680 cu m/day (1.5 mgd to 1.0 mgd) The activated sludge, nitrification and filtration processes have two parallel trains. By selectively using one half of the available units design flow conditions were achieved at one-half the plant design flow rate.

Overall plant performance in terms of BOD_5 and TSS removal was consistent, averaging 95 percent and 96 percent, respectively. Ammonia oxidation was not as consistent, due to loading extremes and cold weather operating conditions. Performance characteristics of two nitrification tower media types (plastic dumped and redwood slats) were different.

The air-fed ozone disinfection system was operated intermittently because of required modifications. Special studies were conducted to determine performance information. When operating, good disinfection performance was achieved.

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Evaluation of Pollution Control Processes

Upper Thompson Sanitation District

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EPA-600/2-80-016
June 1980

EVALUATION OF POLLUTION CONTROL PROCESSES

Upper Thompson Sanitation District

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

This report describes one of the first municipal wastewater treatment facilities specifically designed for two-stage nitrification and effluent disinfection with ozone.

Francis T. Mayo, Director
Municipal Environmental Research
Laboratory

ABSTRACT

The Upper Thompson Sanitation District (UTSD) advanced wastewater treatment facility, located in Estes Park, Colorado, incorporated several unique unit processes. Among these were flow equalization, attached growth nitrification, mixed media filtration and ozone disinfection. Plant design flow was 5,680 cu m/day (1.5 mgd). Average weekly operating flows ranged from 1,140 cu m/day to 3,790 cu m/day (0.3 mgd to 1.0 mgd). The activated sludge, nitrification and filtration processes have two parallel trains. By selectively using one half of the available units design flow conditions were achieved at one-half the plant design flow rate. Therefore the weekly average flow rates during the research project ranged from 40 percent to 134 percent of design and the BOD_5 loading ranged from 14 to 228 percent of design.

Overall plant performance in terms of BOD_5 and TSS removal was consistent, averaging 95 percent and 96 percent, respectively. Ammonia oxidation was not as consistent, due to loading extremes and cold weather operating conditions. Performance characteristics of two nitrification tower media types (plastic dumped and redwood slats) were different. The redwood media performed better during cold weather operation, but the recirculation (R/Q) ratio was about 3 times higher than used for the plastic media. The plastic media performed better during warm weather operation (R/Q ratios similar). Both media types experienced periods of solids sloughing. Neither media type performed at a desired optimum performance level although design requirements were achieved.

The mixed media filters worked well for polishing the nitrification tower effluent under normal conditions, but plugged immediately when extensive solids sloughing from the tower occurred. The filters were also used as part of a denitrification study to demonstrate the effectiveness of dual purpose nitrogen removal and effluent polishing capability. The results showed that denitrification capability existed when methanol was added to the filter influent. Filter plugging after relatively short filter runs (2-3 hours) halted the studies.

The air-fed ozone disinfection system was operated intermittently because of required modifications. Special studies were conducted to determine performance information. When operating, good disinfection performance was achieved, but high ambient ozone concentrations in the working environment plus failure of materials exposed to ozone (piping and diffusers) caused periodic system shutdown. Modifications are indicated for new ozone systems (not completed at the UTSD plant due to cost) so that more cost effective and trouble free operating systems might be possible.

The pressure filter sludge dewatering unit worked well in its application at the UTSD plant, but required a relatively high polymer usage and cost due to the type of sludge dewatered.

This report was submitted in fulfillment of Grant No. R-803831 by the UTSD under the partial sponsorship of the U.S. Environmental Protection Agency. This report covers a period from July 1975 to March 1979, and was completed as of May 1979.

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SECTION 1

INTRODUCTION

The Upper Thompson Sanitation District (UTSD) Wastewater Treatment Plant is located near the mountain community of Estes Park, Colorado. Estes Park is the gateway city to the east entrance of the Rocky Mountain National Park and as such is highly tourist oriented. The rivers in the area are scenic and are used for many recreational purposes, including trout fishing. In an effort to protect the uses of the Big Thompson River and also to protect the tourist industry of the area, the Upper Thompson Sanitation District was formed to provide wastewater treatment services to the area surrounding the Town of Estes Park. To provide these services a new wastewater treatment plant and new collection sewers and interceptors were constructed. The new plant incorporated: flow equalization, activated sludge, fixed film nitrification, mixed media filtration and ozone disinfection. The inclusion of this variety of processes at one plant prompted the United States Environmental Protection Agency (U.S. EPA) to fund a research grant to evaluate the performance, cost and design features of the facility. Data collection for the research project was conducted over a two year period. This report discusses the findings of the research effort.

The UTSD plant design flow rate was 5,680 cu m/day (1.5 mgd). However, the activated sludge, nitrification and filtration processes were designed with multiple components, and therefore, through separate use of these components, design loading rates could be achieved at flow rates less than the total plant design. Initially, the wastewater flow rate from the newly constructed UTSD collection system was not expected to achieve desired flows for the research effort, even if only half of the process components were used. Therefore, as part of the research project, a tie-line between the UTSD collection system and the collection system from another District serving the Town of Estes Park was installed. Supplemental flow from the Estes Park Sanitation District was used to achieve desired flow rates during the research evaluation period.

Two different types of media were evaluated for the fixed film nitrification process, namely redwood media and plastic "dumped" media. These media were evaluated during winter months to determine the effect of temperature on the nitrification process. Ozone was used at the UTSD for disinfection. The ozone system was one of the first full-scale wastewater ozone disinfection systems in the United States. Several "state of the art" problems were encountered and continuous operation was not achieved during the data collection phase of the research project. Some system modifictaions were necessary to achieve continuous operation and others were indicated to achieve a more cost-effective operation. The difficulties encountered during system operation are presented in this report and conclusions are made concerning various aspects of an ozone system's operation, maintenance and design.

The UTSD plant, interceptor, and collection systems were new and were started-up only 3 months before the research project was initiated. Plant start-up problems were encountered which were compounded by a major flood (Big Thompson Flood Disaster - July 1976 [1]) that washed-out a major interceptor line that served the plant (Thompson River Interceptor). Considerable time and effort were expended to recover from the effects of the flood and from a variety of plant start-up problems. As an example, lower than desired plant flow rates occurred during the first summer of data collection due to a reduced tourist trade in the community after the flood.

SECTION 2

PURPOSE AND SCOPE

There were several objectives of the UTSD research project. A major objective was to evaluate the overall performance, cost and design aspects of the UTSD advanced waste treatment facility. Additionally, operating costs, maintenance considerations and costs, and design related considerations were documented and evaluated for each unit process. Evaluation of individual unit processes included several special aspects. Two different media materials were utilized in the nitrification tower: redwood slat and plastic "dumped" media. Each media type was operated for approximately one year during the data collection phase of the research effort. The project also involved a special study to evaluate denitrification performance using the mixed media filters (not an original design capability). Methanol was added as the carbon source for the denitrification process, and performance, maintenance and design aspects regarding denitrification operation using the mixed media filters was evaluated.

The time period for the evaluation of the various processes ranged from two months to two years, with the evaluation of some processes overlapping that of others. The wastewater flow that was treated was all the flow from the UTSD collection system as normally received, plus some of the flow from the Estes Park Sanitation District collection system. The intent was to achieve a wastewater flow rate that would allow most of the processes to be evaluated at design flow conditions (i.e., accomplished by taking some of the multiple components out of service).

SECTION 3

CONCLUSIONS

1. The flow equalization basin provided very satisfactory hydraulic dampening of the flow received at the UTSD wastewater treatment facility.

    A. Daily average flows ranged from 15 percent to 67 percent of the 5,680 cum/day (1.5 mgd) plant design value, and no problems were encountered with sufficient basin storage capacity for flow equalization.

    B. The basin effluent pinch valve flow controller assembly controlled the flow rate ±2% from the set rate, when functioning.

        1) At very low flow rates the pinch valve was severely restricted and maintenance problems developed with the flow control assembly.

        2) An isolation plug valve located on the basin effluent line was used to control flow when the pinch valve was not working, and the flow rate was controlled to a variation of ±15 percent of the set rate.

2. Aeration and mixing were not provided in the original design of the UTSD flow equalization basin, but no major operational or performance problems were associated with this mode of operation.

A. Fall, winter and spring basin effluent D.O. concentrations were above 1 mg/l. Summer D.O. concentrations were below 1 mg/l, but no odor problems were evident.

B. Relatively low wastewater temperatures and/or immediate removal of settleable solids from the flow equalization basin were felt to be contributing factors to the absence of odor problems from the flow equalization system.

C. Other than D.O. concentrations, no significant chemical or biological changes in wastewater characteristics occurred within the flow equalization basin.

D. A 1.2 cm to 2.5 cm (1/2 in. to 1 in.) grease build-up occurred on the basin walls. Periodic cleaning prevented further build-up and also prevented odor problems from developing.

3. The aerated grit removal proces consistently performed in a satisfactory manner.

4. The activated sludge process experienced extreme variations in hydraulic and organic loading, and variable effluent BOD_5, TSS, and NH_4-N concentrations occurred.

A. The wastewater flow rate and BOD_5 load during the project averaged less than design (i.e. design was 2840 cum/day (0.75 mgd)) with one half of the activated sludge units in service , but reached a level much greater than design during the summer tourist season.

1) Flow averaged 65 percent of design, but reached levels of 134% of design values. The BOD_5 loading averaged 60 percent and reached levels of 228 percent of design values.

2) High flow and BOD_5 loadings during the summer tourist season of the year (3 months), degraded activated sludge effluent quality.

B. Low flow and BOD_5 loadings occurred during the fall, winter and spring seasons of the year (9-months), and nitrification occurred in the activated sludge process during a portion of that time.

1) During this period, BOD_5 loading averaged 50 percent of design.

2) Extensive ammonia oxidation occurred during the fall until the Christmas holiday tourist season.

3) Ammonia oxidation abruptly stopped when the BOD_5 load in creased by 140 percent during the one-week Christmas holiday season of 1976 and 1977.

4) Ammonia oxidation did not re-occur after the Christmas holiday flows subsided, probably due to the low temperature of the wastewater (4-5°C).

5) Very low aeration basin biomass concentration was implemented during the fall of 1976 to discourage nitrification. No control over aeration basin dissolved oxygen concentration was exercised.
   a) MLVSS concentration was 920 mg/l.
   b) Extensive nitrification was not eliminated.
   c) BOD_5 removal efficiency was 76 percent.

6) Higher aeration basin biomass concentration was implemented during the fall of 1977 to improve BOD_5 removal. No control over aeration basin dissolved oxygen concentration was exercised.

a) MLVSS concentration was 2830 mg/l.

b) Extensive nitrification occurred.

c) BOD_5 removal efficiency improved to 88%.

5. The fixed-film nitrification process experienced extreme fluctuations in ammonia loading and wastewater temperature, and variable ammonia oxidation occurred. Each media type (redwood and plastic dumped) was operated under a start-up, cold weather and warm weather period.

A. For both media types the volume (one side of tower) was identical at 386 cu m (13,780 cu ft). Specific surface area for the plastic dumped media was 89 sq m/cu m (27 sq ft/cu ft) and for the redwood 46 sq m/cu m (14 sq ft/cu ft).

B. Acclimation of nitrifying organisms during the start-up periods for both media types was severely limited because of low ammonia loading to the tower (activated sludge system was nitrifying).

C. Cold weather operation for both media types included an abrupt increase in the ammonia loading to the tower following the Christmas holidays. Different oxidation capabilities were noted for each media type, but different operating procedures also occurred.

1) Overall oxidation performance during cold weather operation for both media types averaged 25 percent for the redwood media and 30 percent for the plastic media, but good pre-winter start-up conditions did not exist.

2) Plastic media NH_4-N oxidation averaged 3.6 kg/day (8 lb/day) and reached a maximum oxidation of 6.8 kg/day (15 lb/day). The tower recirculation ratio (R/Q) was relatively low at 0.74.

3) Redwood media NH_4-N oxidation averaged 5.9 kg/day (13 lb/day) and reached a maximum oxidation of 9.5 kg/day (21 lb/day). The tower R/Q ratio was 2.2.

D. Warm weather operation for both media types included very high ammonia loadings (166 percent design), and different oxidation capabilities were noted for each media type. Also, different operating characteristics were observed.

1) Plastic media oxidation capability initially increased rapidly during warm weather, and reached a maximum oxidation rate of 36 kg/day (80 lb/day) or about 40 percent of the total NH_4-N loading. The R/Q ratio was 0.74.

2) Redwood media oxidation capability responded more slowly, and reached a maximum oxidation rate of 23 kg/day (50 lb/day) which was also about 40 percent of the total NH_4-N loading. The R/Q ratio was 0.77.

3) Both media types appear to achieve a maximum oxidation rate which would indicate that nitrification system design should be based on peak daily or peak weekly values.

4) Specific area (dry media) oxidation rates corresponding to the apparent maximum oxidation capability were:

Plastic = 1.03 gm/day/sq m (0.21 lb/day/1000 ft^2 media surface

Redwood = 1.27 gm/day/sq m (0.26 lb/day/1000 ft^2 media surface

Plastic specific area oxidation rate was 20% less than redwood, but the plastic media had 52% more total media surface area [i.e. 89 sq m/cu m (27 ft^2/ft^3) versus 46 sq m/cu m (14 ft^2/ft^3)].

5) Excessive solids sloughing from the nitrification tower immediately plugged the mixed media filters and occurred with both media types.

   a) The plastic media experienced relatively frequent (weekly) excessive solids sloughing conditions.

   b) The redwood media experienced limited (monthly) excessive solids sloughing, and not to the extreme that was experienced with the plastic media.

E. Important, updated information concerning redwood cold weather tower performance was developed after the data collection phase of the research project was over, and when better pre-cold weather tower start-up conditions were experienced.

1) Dissolved oxygen control in the activated sludge aeration basin was used to inhibit nitrification which allowed higher ammonia loadings to the nitrification tower.
2) An average 94 percent ammonia oxidation occurred in the fall of 1978 when the tower loading was 26 gm/day/cu m (1.6 lb/day/1000 ft^3) or 24 percent of design load.
3) Some increase in ammonia oxidation occurred when the 1-week Christmas holiday ammonia load reached an average 39 kg/day (85 lb/day) or 91 percent of design.

   a) Higher levels of ammonia oxidation were achieved during this higher loading period, but the percent of incoming ammonia oxidized decreased to a low of 42 percent.

   b) Acclimation of the tower to an expected higher loading may be necessary through artificially feeding ammonia by chemical addition methods prior to receipt of the load.

4) Subsequent to the Christmas holiday season and during cold weather operation, ammonia load dropped to pre-holiday levels. Ammonia oxidation decreased from 13.6 kg/day to 7.3 kg/day (30 lb/day to 16 lb/day), while tower effluent wastewater temperature varied from 1°C to 4°C. The tower R/Q ratio was similar to te previous winter at 2.0, and the indication was that a significant cold weather effect on nitrification performance occurred.

F. Bench tests indicated that lower temperature and low pH significantly reduced the rate of ammonia oxidation, but given sufficient time complete nitrification always occurred.

1) Lower nitrification rates are probably experienced at the UTSD Plant because of low winter time wastewater temperature (1°C to 4°C) and overall lower wastewater pH and alkalinity (typically less than 6.5 and 100 mg/l, respectively).

2) Additional time (i.e. more tower media by simultaneouly placing into service both towers) and/or higher pH (i.e. alkalinity addition) may be necessary to consistently achieve high levels of ammonia removal under present loading conditions at the UTSD facility.

G. Better ammonia oxidation capability for both media types was associated with a higher R/Q ratio (i.e. greater than 2 rather than less than 1), although an optimum R/Q ratio was not determined.

6. Denitrification capability was the subject of a special study and commenced when methanol was added to the influent to the mixed media filters. Extensive filter plugging due to biological growth forced the study to be halted.

A. An acclimation time of 7 days was required for the system to reach full NO_2/NO_3-N removal potentional.

   1) Wastewater temperature was about 10°C.

   2) Acclimation time excludes the time when the amount of methanol added was less than the D.O. requirement of the wastewater.

B. To achieve 90 percent NO_2/NO_3-N removal, the methanol to nitrate (M/N) ratio was about 4.4.

C. Extensive filter plugging (i.e. backwashing required every 2-3 hours) occurred within 2-3 weeks and caused the study to be halted.

7. The mixed media filter process worked well to polish the nitrification tower effluent, but had to be bypassed when extensive sloughing of solids from the tower occurred.

   A. An average 65 percent to 75 percent reduction in the BOD_5, TSS, and turbidity values occurred. Respective effluent concentrations were 10 mg/1, 6 mg/1 and 2.1 NTU, excluding the times when the filter was bypassed because of plugging problems due to tower sloughing.

   B. The tower's excessive solids sloughing caused the filter to plug within 10 minutes, and forced the filters to be bypassed until sloughing ceased.

8. The ozone disinfection process was the subject of a special study. Several state of the art problems occurred which hindered continuous operation, but important information was developed regarding system operation, maintenance and design as follows:

A. The "Dasibi Meter" continuous measurement ozone concentration meter readings correlated well with wet chemistry results, after the meter was properly set up and calibrated.

1) Ozone and purge air flow to the meter was controlled at 2 l/min.

2) The meter span setting was adjusted based on wet-chemistry results.

B. The ozone generator periodically "flooded" and was damaged due to malfunctions within the air pretreatment system.

1) A cobaltous chloride color changing indicator that was provided to show an increase in air dew point was not sensitive to gradual changes, and potential problems associated with dew point could not be detected until far along.

2) A dew point meter was more sensitive to gradual changes in dew point, but "flooding" still occurred when the meter was monitored only once per day.

3) A dew point meter with associated high dew point level alarm and/or automatic system shutdown would substantially reduce generator "flooding" potential.

4) The dew point meter should be checked against a dew point cup measuring instrument to verify meter accuracy and/or properly set the high dew point level alarm.

C. The air pretreatment refrigerant drier required special maintenance considerations.

1) The drier voltage of 440 volts was compatible with the voltage of the ozone generator, but required special order parts because 220 volt refrigeration units were more common in the community.

2) Repairs to the refrigerant drier were quite technical and had to be completed by an experienced repair man who had special equipment.

D. More information should be developed by ozone equipment manufacturers on ozone production versus dew point levels over the entire ozone generator operation range, to provide design engineers and plant operators with a better basis for ozone system design and operation.

E. Ozone production of the UTSD ozone generators was not significantly lower at air flow rates of 79 cu m/hr (47 scfm) as opposed to air flow rates of 118 cu m/hr (70 scfm).

F. Ozone generation system power utilization at the UTSD plant was greater at lower ozone production levels due to the relatively constant power requirements of the air pretreatment unit, and caused inefficient power usage under current operating conditions.

1) Total power utilization varied from about 55 kWh/kg (25 kWh/lb) at production levels of 0.32 kg/hr (17 lb/day) to 33 kWh/kg (15 kWh/lb) at production levels of 1.08 kg/hr (57 lb/day).

2) Lower ozone production levels of 0.32 kg/hr (17 lb/day) are usually sufficient at the UTSD plant for current wastewater flow rates and ozone dosage requirements, thus the least efficient power utilization values presently exist.

3) More efficient power utilization values over the entire range of ozone generation system operation would improve system power consumption and cost at lower than design wastewater flow rates and ozone dosage requirements, and should be considered for all ozone system designs.

G. Contact basin off-gas, ozone discharge and other sources of ozone leakage have caused excessively high ambient ozone concentrations in and around the plant area, and has required that several system design modifications be made.

1) The contact basin had to be totally covered and sealed.

2) The off-gas exhaust system was redesigned.

3) The basin baffles and scum skimmers were modified.

4) The unplastized polyvinyl chloride (UPVC) ozone piping was replaced with stainless steel piping.

5) The ozone off-gas must be destroyed. A heat/catalyst ozone destruct unit was designed and constructed.

H. An epoxy joint on the original ozone diffusers was not ozone resistant and failed. As a result, new diffusers with a mechanical joint had to be installed.

I. The UTSD ozone contact basin was designed for 90 percent transfer efficiency and was based on incomplete information.

1) Ozone transfer efficiency was variable and was affected by wastewater quality.

a) Typically, the transfer efficiency was between 50 and 60 percent.

b) The transfer efficiency increased when the wastewater quality was poor.

c) With good wastewater quality, measured ozone transfer efficiencies correlated well with ozone/liquid gas transfer theory.

2) To ensure achieving a desired, minimum transfer efficiency, ozone contact basin design should be based on ozone/liquid gas transfer theory.

J. Good disinfection performance has occurred at the UTSD plant when the ozone diffusers were in good condition and the system was operated consecutively for several days.

1) Effluent fecal coliform concentrations averaged less than the design requirement of 200 per 100 ml at applied ozone dosaes of about 7 mg/l.

2) When the ozone system was operated for only a short period of time, poor disinfection was experienced and increased effluent TSS concentrations occurred due to biological slime growth sloughing off of the contact basin walls and piping.

9. The sludge dewatering unit functioned very satisfactorily in its application at the UTSD plant.

A. The sludge dewatered during the research period had been contained in the aerobic digester for a long period of time, and was quite inert and difficult to dewater.

1) The VS/TS ratio was 58 percent.

2) The specific oxygen uptake rate was less than 0.5 mg/hr/gm VSS.

B. A 60-day dewatering test was conducted with the following results:

1) The total amount of sludge dewatered during the 60-day period was 18.9 metric dry tons (20.8 dry tons).

2) The dry weight percentage of solids in the dewatered sludge was 11 percent.

3) An average production rate of 99 kg/hr (217 lb/hr) of dry solids occurred.

4) The polymer dosage required was 25 kg/metric ton (50 lb/ton) of dry sludge.

5) The polymer cost was ($62.22/ton) of dry sludge.

10. The total capital cost for the 5,680 cum/day (1.5 mgd) UTSD wastewater treatment plant was approximately 3 million dollars. The average operating cost at existing wastewater flow rates which were 32 percent of design and excluding research-associated costs, was $123,064 per year or 18.6¢/cum (70.3¢/1000 gal) treated.

SECTION 4

RECOMMENDATIONS

1. Prior to the peak flow, summer tourist season, acclimation of the activated sludge system for the increased loading should be initiated.

2. Modify operation of nitrification tower as indicated by results of the research project.

    A. Place into service both sides of the tower to provide additional contact time to overcome the nitrification rate reducing effects of the wastewater's low temperature, and relatively low alkalinity and pH values.

    B. In general, maintain increased tower recirculation (R/Q) ratios and maintain constant tower wetting rates. Continue to evaluate performance to determine the optimum R/Q ratio.

    C. Discourage ammonia oxidation in the activated sludge system, by decreasing the D.O. concentration in the aeration basins.

3. Substantially decreased filter hydraulic loading rates should be investigated with respect to using mixed media filters for the dual purpose of denitrification and effluent polishing.

4. Special considerations should be incorporated into ozone disinfection system designs.

A. Incorporate a dew point meter with a high dew point level alarm and/or automatic system shut-down in all air pretreatment unit designs, in order to reduce generator "flooding" potential.

B. Require ozone generator manufacturers to provide ozone production information for various dew point levels and for the entire ozone generator operating range, in order to provide design engineers and plant operators with a better basis for ozone system design and operation.

C. Provide for more efficient power utilization over the entire range of ozone system production, in order to improve system power consumption and operating cost at lower than design wastewater flow rates and/or ozone dosage requirements.

D. Base the design minimum transfer efficiences for ozone disinfection system contact basins on ozone/liquid gas transfer theory, in order to be assured of consistently good disinfection performance as well as consistently achieve expected ozone transfer efficiencies.

E. Provide ozone destruction capability for the contact basin off-gases.

F. Provide suitable grade stainless steel piping for ozone gas distribution.

SECTION 5

DESCRIPTION OF FACILITIES

The Upper Thompson Sanitation District (UTSD) Wastewater Treatment Plant was one of two plants serving the Town of Estes Park and the surrounding community. The UTSD was formed in 1971 to primarily serve the area surrounding the Town. The Estes Park Sanitation District served the Town of Estes Park. The wastewater treated at both facilities was mostly domestic.

The UTSD treatment plant, collection lines, and a portion of the interceptor sewers were constructed co-currently and were placed in operation in March, 1976. Line construction in the Estes Park area was expensive and difficult because of the rugged mountain terrain. Delayed construction of some of the UTSD collection system was an area of concern with respect to the volume of flow that would initially be treated at the UTSD plant during the research project. It was desired to treat a level of flow approaching the design loading rate of the plant. About 1,140 cu m/day (0.3 mgd) was expected from the initial UTSD lines. Additional flow was obtained from the Estes Park Sanitation District through a tie-line that was constructed as part of the research project.

Wastewater flow in the Estes Park and UTSD service areas varied significantly from summer to winter because of a high influx of tourists during the summer months. The average winter flow at the UTSD facility during the research project was about 1,510 cu m/day (0.40 mgd), while the average summer flow was about 3220 cu m/day (0.85 mgd). These averages included the flow from the Estes Park tie-line. The overall average plant flow during the project was 1,930 cu m/day (0.51 mgd), and therefore about 70 percent of the design loading was achieved by operating one-half of the plant units.

A flow schematic for the UTSD facility is shown in Figure 1. All wastewater was pumped to the plant from lift stations serving two river basins and was directed to a flow equalization basin. Equalized flow was directed to the grit chamber then to the activated sludge process. Secondary clarifier effluent was pumped over the nitrification tower and was then directed to the flow equalization basin. Equalized flow was directed to the grit chamber then to the activated sludge process. Secondary clarifier effluent was pumped over the nitrification tower and was then directed to the mixed media pressure filters. Filter effluent was disinfected in the ozone contact basin, directed through a filter backwash water storage tank and discharged to the Big Thompson River. All sludge produced in the plant was eventually settled in the secondary clarifier. Waste sludge and scum was pumped to an aerobic digester for stabilization and mass reduction. Digested sludge was dewatered by a pressure roller filter and was hauled to a sanitary landfill. All

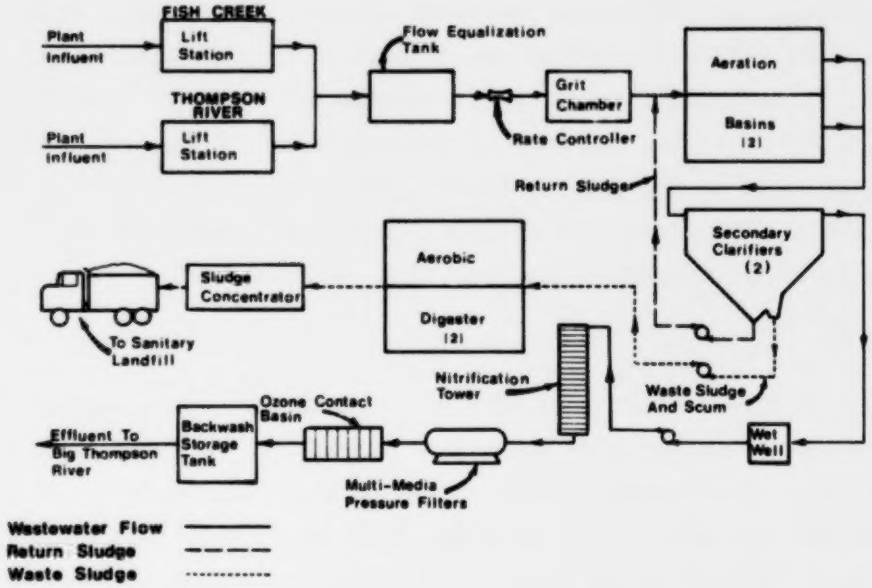

Plant Influent
FISH CREEK
Lift Station
THOMPSON RIVER
Plant Influent
Lift Station
Flow Equalization Tank
Grit Chamber
Rate Controller
Aeration
Basins (2)
Return Sludge
Secondary Clarifiers (2)
Aerobic
Digester (2)
Sludge Concentrator
To Sanitary Landfill
Nitrification Tower
Waste Sludge And Scum
Wet Well
Ozone Contact Basin
Backwash Storage Tank
Effluent To Big Thompson River
Multi-Media Pressure Filters
Wastewater Flow
Return Sludge
Waste Sludge

Figure 1. Plant flow schematic diagram of the Upper Thompson Sanitation District Wastewater Treatment Plant.

internal side stream flows were directed back to the Thompson River Lift Station. A well equipped laboratory was provided for process evaluations.

Due to the elevation of the UTSD facility (2,290m (7,500 ft) above sea level), all treatment units except the nitrification tower were covered for protection from the weather as well as for aesthetic purposes. The nitrification tower was open to the atmosphere to allow for oxygen transfer. About 0.91 m (3 ft) of freeboard above the tower media provided for some weather protection.

RAW WASTEWATER PUMPING - LIFT STATIONS

The UTSD collection system served two drainage basins in the Estes Park area, Fish Creek and Big Thompson. The collection system in the Big Thompson basin is the bigger of the two, and during the research project about 90 percent of the total plant flow was received from this basin. All wastewater that was collected from both systems was pumped to the treatment plant. The Thompson River lift station was located at the plant site and the Fish Creek lift station about one-half mile from the plant.

The lift stations consisted of a wet-well, dry-well, pumps and a comminutor with bar screen by-pass. The characteristics of each lift station is shown in Table 1.

TABLE 1. FISH CREEK AND THOMPSON RIVER LIFT STATION CHARACTERISTICS

Item	Description
- Fish Creek Lift Station	
Wet-Well Capacity	8,250 gal
Pumps	
Number	3 - 40 hp each
Capacity (each)	900 gpm
Communitor	
Number	1
Capacity	4.0 mgd

(continued)

TABLE 1. (Continued)

Item	Description
- Thompson River Lift Station	
Wet-Well Capacity	9,430 gal
Pumps	
Number	3 - 25 hp each
Capacity (each)	1,350 gpm
Comminutor	
Number	1
Capacity	7.4 mgd

gal x 3.785 = l; gpm x 0.0631 = l/sec; mgd x 3785 = cu m/day; hp x 0.746 = kw

FLOW EQUALIZATION

Flow from both lift stations was directed to the flow equalization basin. Effluent flow rates from the basin were then controlled to provide a consistent flow rate to the downstream unit processes. The flow equalization system was constructed to dampen the highly variable daily flow rate conditions expected and to facilitate optimum performance of the downstream processes in order to produce a consistently high quality effluent.

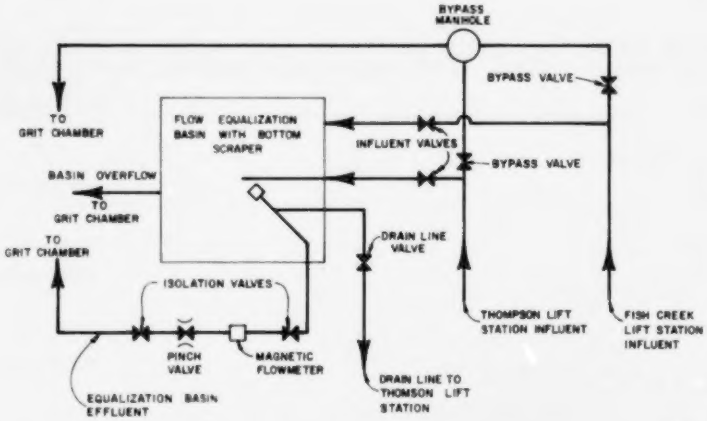

BYPASS MANHOLE
BYPASS VALVE
TO GRIT CHAMBER
FLOW EQUALIZATION BASIN WITH BOTTOM SCRAPER
INFLUENT VALVES
BYPASS VALVE
BASIN OVERFLOW
TO GRIT CHAMBER
TO GRIT CHAMBER
DRAIN LINE VALVE
ISOLATION VALVES
THOMPSON LIFT STATION INFLUENT
FISH CREEK LIFT STATION INFLUENT
PINCH VALVE
MAGNETIC FLOWMETER
DRAIN LINE TO THOMSON LIFT STATION
EQUALIZATION BASIN EFFLUENT

Figure 2. Equalization basin flow schematic diagram.

The major components of the flow equalization system include the equalization basin, which was equipped with a scraper mechanism and a water level indicator-recorder; a magnetic flow meter with inputs to a flow indicator-recorder-totalizer and to the flow control system; and a modulating pinch valve complete with actuator and automatic control system. A flow diagram showing the piping location and valves is shown in Figure 2. The basin characteristics are shown in Table 2.

TABLE 2. FLOW EQUALIZATION BASIN CHARACTERISTICS

Characteristic	Description
Shape	Rectangular with sloped bottom
Sidewater depth	12 ft
Capacity of sloped area	520 gal
Capacity of rectangular area	324,900 gal
Total storage capacity	325,400 gal
Scraper Mechanism - corner sweep	0.5 hp

ft x 0.305 = m; gal x 3.785 = 1; hp x 0.746 = kW

Equalized flow was obtained by means of a pinch valve assembly, located on the effluent line, which was operated and controlled by a combined electronic/pneumatic system that utilized a flow signal from a magnetic flow meter. Once a desired flow rate was obtained, the pinch valve opened and closed as necessary to compensate for an increase or decrease in the level of the basin. As the level increased due to a higher basin influent flow rate, the pinch valve closed to compensate for the increased head which would tend to increase flow above the desired rate. Conversely, as the basin level decreased due to a lower basin influent flow rate, the pinch valve opened to compensate for the decreased head which would tend to decrease flow below the desired rate. The operation was completely automatic, and once a flow rate is set it is maintained unless the basin emptied. The set flow rate could be exceeded if the rate was set to low and the basin filled and overflowed.

No aeration or mixing of the contents of the basin was provided. It was expected that septicity conditions in the basin would not occur. However, provisions were made to add a jet aeration mixing system if septicity became a problem. Without mixing, settleable organic material which entered the basin was scraped to the hopper discharge and immediately removed. As such the flow equalization basin did not provide for equalization of the plant loading in the form of settleable solids.

The flow equalization system included the plant influent flow monitoring system. A magnetic flowmeter was used to provide flow information as well as control of the pinch valve. However, this meter was bypassed if the flow to the equalization basin was bypassed to the aerated grit chamber. Under this condition plant flow could be measured using the mixed media filter effluent flow measuring instruments.

GRIT REMOVAL

The major components of the grit chamber include the grit basin, the air diffusion system and the classification equipment. The grit system characteristics are shown in Table 3.

TABLE 3. GRIT REMOVAL SYSTEM CHARACTERISTICS

Characteristic	Description
Shape	Rectangular with hoppered bottom
Volume	18,750 gal
Settling Velocity	1 ft/sec.
Grit Quality	80 to 100 mesh
Compressor	15 hp

gal x 3.785 = l; ft/sec x 0.3048 = m/sec; hp x 0.746 = kW

Flow from the equalization basin, flow bypassed around the equalization basin, or flow that overflowed the equalization basin was direcetd to an aerated grit chamber where grit material was settled out and collected in the chamber's hoppered bottom. The settled material was then pumped to a centrifugal classification unit where organic material that had settled in the chamber was separated from the grit. The dewatered grit material was then stored in containers for disposal at a sanitary landfill. Air was supplied to the grit basin to provide a method of controlling the settling velocity of the material within the basin and to enhance grease flotation. Grease retained in the aerated grit chamber was manually removed.

ACTIVATED SLUDGE

The major components of the activated sludge process include the aeration system, clarification system and sludge pumping systems. A description of each system and a discussion of the operational aspects of each system is presented below.

Aeration System

The aeration system was comprised of the aeration basins, and oxygen transfer and basin mixing equipment. Aeration basin mixing and oxygen transfer was accomplished by a combination of mechanical mixers (fixed pier submerged turbine) and a supply of compressed air. Compressed air from blowers was discharged into the aeration basins directly beneath the submerged turbines. The compressed air formed large bubbles upon release into the liquid which were sheared into smaller bubbles and dispersed by the mixer. The required mixing of the basin contents was supplied by the submerged turbines.

Two identical basins with a common center wall were provided. Both basins were provided with separate influent flow control, return sludge lines, and air supply lines. A dividing gate was located on the common wall separating the two basins. This gate provided for flexible use of the basins. The basins could be operated independent of one another or could be used together in a variety of flow patterns. During the research project the gate was closed which allowed only one basin to be used. The basin characteristics are summarized in Table 4.

TABLE 4. AERATION BASIN CHARACTERISTICS

Characteristics	Description
- Aeration Basins	
Number	2
Surface Dimensions (each)	63 ft x 31 ft
Sidewater Depth (each)	17 ft
Capacity (each)	248,000 gal
Detention Time (No recirculation included)	
One Basin @ 0.75 mgd	7.9 hr
Two Basins @ 1.5 mgd	7.9 hr
- Turbine Mixers	
Number (per basin)	2
Size	25 hp
- Air Blowers*	
Number	3
Capacity (each)	1200 scfm
Size (each)	75 hp

*Blowers also used for aerobic digester air supply.
ft x 0.305 = m; gal x 3.785 = 1; hp x 0.746 = kW; cfm x 0.028 = cu m/min

Clarification System

The clarification system consisted of two clarifier basins each with a sludge collection mechanism. The clarifiers were center feed and peripheral withdrawal units and were equipped with both a surface and bottom scraper mechanism for removing scum and sludge, respectively. Scum was moved to a scum hopper and pumped to the aerobic digester. Sludge was returned back to the aeration basin or was wasted. Return sludge was withdrawn from the clarifier using a rapid withdrawal mechanism. Sludge to be wasted was scraped to a sludge hopper located at the center of each clarifier and was pumped to the aerobic digesters. The clarifier characteristics are summarized in Table 5.

TABLE 5. CLARIFIER CHARACTERISTICS

Characteristic	Description
- Clarifiers	
Number	2
Diameter (each)	40 ft
Surface area (each)	1,256 sq ft
Sidewater depth (each)	10 ft
Weir Length (each)	126 ft
Capacity (each)	98,500 gal
Overflow rate* 0.75 mgd	600 gal/day/sq ft
Weir Overflow Rate*	5,970 gpd/ft
Hydraulic D.T.*	3.2 hr.
- Waste sludge hopper	
Location	bottom of clarifeir
Capacity	100 gal
- Sludge Mechanism	
Type	Combined rapid withdrawal with bottom scrapers
Drive Motor	0.33 hp

ft x 0.305 = m; sq ft x 0.093 = sq m; gal x 3.785 = cu m gal/day/sq ft x 0.041 = cu m/day/sq m; hp x 0.746 = kW; gal/day/ft x 0.0124 = cu m/day/m
* One basin in service @ 0.75 mgd

Sludge Pumping Systems

The activated sludge pumping system consisted of two return sludge pumps and one waste sludge pump. The return sludge pumps were variable non-clog centrifugal pumps and could be operated independently or together. The pump discharge was directed to the aeration basin, but could be directed to the aerobic digester, if desired. The return sludge flow rate was measured using a venturi tube. Flow rates were indicated adjacent to the pumps and on the main control panel. The waste sludge pump was a constant speed vortex pump. The waste sludge flow rate was measured using a magnetic type flow meter and was indicated and totalized. A summary of the characteristics of the activated sludge pumping system is shown in Table 6.

TABLE 6. ACTIVATED SLUDGE PUMPING CHARACTERISTICS

Characteristics	Description
- Return Sludge Pumps	
Number	2 - 5 hp each
Type	Variable speed non-clog centrifugal
Capacity	250 - 1200 gpm
- Return Sludge Flow Meter	
Number	1
Type	Venturi Tube
- Waste Sludge Pump	
Number	1 - 1.5 hp
Type	Constant Speed Vortex
Capacity	100 gpm
- Waste Sludge Metering	
Number	1
Type	Magnetic Meter

gpm x 0.0631 = l/sec; hp x 0.746 = kW

NITRIFICATION

Effluent from the activated sludge system was directed to a wet-well and pumped to an attached growth nitrification tower. The tower media was originally designed to be redwood slats. However, in conjunction with the research project the tower was divided into two equal sections and two types of media (redwood and dumped plastic) were installed. Flow could be directed to one side of the tower only, or to both sides depending on flow conditions. During the research project only one side of the tower was operated at a time. A summary of the nitrification system characteristics is shown in Table 7.

TABLE 7. NITRIFICATION TOWER CHARACTERISTICS

Characteristic	Description
- Wet-Well Capacity	59,500 gal
By-Pass	Overflow to ozone contact basin
- Pumps	
Number	2 - 30 hp each

(continued)

TABLE 7. (Continued)

Characteristic	Description
Type	Variable speed non-clog centrifugal pumps
Capacity (each)	0 - 2250 gpm
- Nitrification Tower	
Media Depth	14 ft
Surface Area (one side)	984 sq ft
Volume (one side)	13,780 cu ft
Hydraulic loading rate (each side) @ 0.75 mgd and no recycle	0.53 gpm/sq ft
Ammonia loading rate (each side) @ 0.75 mgd and 15 mg/l NH_4-N	6.8 lb NH_4-N/day/1000 ft^3
Recycle Rate (maximum) @ 0.75 mgd and one pump	4:1
- Media (Specific Surface Area)	
Redwood Media	14 sq ft/cu ft
Plastic Dumped Media	27 sq ft/cu ft
- Distribution System	
Type	Fixed
Nozzles	Vari-flow

ft x 0.305 = m; sq ft x 0.093 = sq m; cu ft x 0.028 = cu m; sq ft/cu ft x 3.28 = sq m/cu m; gal x 3.785 = l; gpm x 0.0631 = l/sec; gpm/sq ft x 40.7 = l/min/sq m; lb/day/1000 ft^3 x 16 = sq m/cu m; hp x 0.746 = kW.

Two variable speed non-clog centrifugal pumps were used to pump activated sludge effluent to the nitrification tower. Secondary effluent was distributed over the tower surface through a fixed nozzle distribution system. The nozzles that were originally installed had a fixed splash plate design and poor flow distribution over the media surface occurred especially at lower flow conditions. These splash plates were later replaced with spring loaded splash plates (Neptune Microfloc Vari-flow nozzles) and good distribution was obtained even with variable flow rates to the tower.

Flow through the tower was directed to a wet-well located beneath the tower. Gravity flow from the wet well was directed to the mixed media filters (the level of flow in the wet well served to pressurize the filters). Additionally, a controlled and measured portion of the tower flow could be recycled back to the towers.

MIXED MEDIA FILTRATION

The filtration system consisted of a chemical addition and rapid mixing system, four pressure filter vessels, a backwash water storage basin and a backwash wastewater storage basin. A summary of the mixed media filtration system characteristics is shown in Table 8.

TABLE 8. MIXED MEDIA FILTER CHARACTERISTICS

Characteristic	Description
- Mixed Media Filters	
Number	4
Shape	Cylinderical (8 ft diameter x 18 ft long)
Media Surface Area (each)	144 sq ft (8 ft dia x 18 ft long)
Media	Anthracite coal, sand and gravel
Underdrains	Perforated PVC pipe lateral placed in support gravel
Surface Wash (each)	Three - six foot diameter water-jet rotary sweep.
Vessel Relief Valves	Air and pressure relief valves
Loading Rate	
Recommended	5 gpm/sq ft
Actual @ .75 mgd with 2 filters	3.6 gpm/sq ft
- Backwash System	
Backwash Pumps	
Number	2 - 40 hp each
Type	Constant speed centrifugal
Capacity (each)	2,500 gpm
Backwash Supply Storage Volume	42,000 gal
- Surface Wash Pump	
Number	1 - 15 hp
Type	Constant speed centrigual
Capacity	200 gpm
- Backwash Wastewater Basin	
Storage Volume	40,000 gal
Discharge	Thompson River Lift Station
- Chemical Feed Systems	
Feed Pumps (Alum)	
Number	2
Type	Diaphragm
Capacity	2 to 50 gph
Alum Storage Volume	4,000 gal

(Continued)

TABLE 8. (Continued)

Characteristic	Description
Polymer Feed Pumps	
Number	1
Type	Diaphragm
Capacity	1-22 gph
Polymer Preparation	Dry Polymer Mix System
In-Line Mixer	1 - Walker Process Instro-Mix

sq ft x 0.093 = sq m; ft x 0.305 = m; gpm/sq ft x 40.7 = 1/min/sq m; gpm x 5.45 = cu m/day; gal x 3.785 = 1; gph x 0.091 = cu m/day; hp x 0.746=kW.

A coagulant aid could be added to the influent to the filters through an in-line flash mixer. Liquid chemical storage and feed pumps and dry chemical preparation and feed pumps were provided as part of the coagulant aid system. Chemicals could also be added at the effluent weir of the activated sludge aeration basins and at the nitrification tower wet well. This flexibility allowed the chemical feed system to be used to add chemicals for phosphorus removal and/or chemicals for alkalinity adjustment. As part of the research project a methanol feed system was installed whereby methanol could be added to the mixed media filter influent at the in-line mixer. The purpose of the methanol addition was to evaluate denitrification capability using the media of the filters to support the denitrifying organisms.

The filter backwash system was provided to release and return all particles that had been trapped in the filter media to the head of the plant. An automatic system for initiating and controlling the backwash sequence was provided. When the head loss through a filter reached a predetermined level, the filter was taken off line, backwashed and returned to service. The backwash cycle could also be initiated manually by the plant operators and this procedure was used during the project. Components of the backwash system included the backwash water storage basin, backwash and surface wash pumps, and the instrumentation and control equipment to operate the system.

The backwash water storage basin was located directly beneath the administrative offices, and contained ozonated plant effluent. A morning glory overflow weir in the basin directed plant effluent from the basin to the plant outfall line.

Backwash wastewater from the filters was stored in a concrete storage basin located beneath the laboratory. The discharge from the basin was directed to the Thompson River Lift Station at a controlled rate, pumped to the flow equalization basin and directed back through the plant.

OZONE DISINFECTION

The UTSD ozone disinfection process was one of the first full-scale ozone wastewater disinfection processes in the United States. Several "state of the art" problems were encountered and modifications to the original ozone system design were necessary. In this section of the report the ozone system is described as it was modified. The reason for and the extent of the modifications are discussed later in the report. Ozone disinfection was an area of special study; consequently, the following section contains a detailed description of the disinfection system.

The ozone disinfection process consisted of two air-fed ozone generator units and one ozone contact basin. Each generator unit was designed to provide adequate disinfection at the plant design flow rate. The second generator unit was provided for stand-by. The two units were identically constructed and were labeled No. 1 and No. 2. A summary of the ozone system characteristics is presented in Table 9.

TABLE 9. OZONE DISINFECTION SYSTEM CHARACTERISTICS

Characteristic	Description
- Generation System	
Number	2
Air Pretreatment (2 units)	
Components	Compresser(15 hp each), cooler, drying tower
Capacity	78 scfm (drying tower limitation)

(Continued)

TABLE 9. (Continued)

Characteristic	Description
Dew Point (maximum)	-51°C
Generator (2 units)	
Manufacturer	Welsbach
Type	"Iron Lung"
Capacity @ 1% by weight	76 lb/day
Dosage @ 1.5 mgd	6 mg/l
Cooling System (1 unit)	
Media	Well Water
Capacity	20 gpm
- Contact Basin	
Ozone Transfer	Fine Bubble Tube Diffusers
Shape	Rectangular, with vertical serpentine flow pattern
Volume	14,500 gal
Detention Time @ 1.5 mgd	14 min

cfm x 0.028 = cu m/min; lb/day x 0.454 = kg/day; gpm x 0.063 = l/sec; gal x 3.785 = l; mgd x 3785 = cu m/day; hp x 0.746 = kW.

Ozone was generated by two Welsbach air-fed units, Model CLP-68F20L. A schematic diagram of the ozone generation equipment is shown in Figure 3.

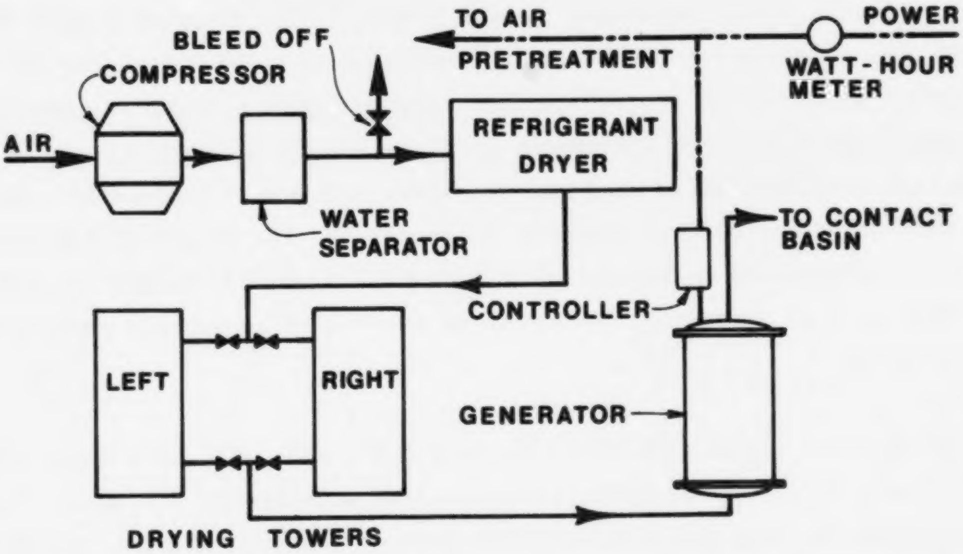

TO AIR
PRETREATMENT
POWER
WATT-HOUR
METER
BLEED OFF
COMPRESSOR
AIR
REFRIGERANT
DRYER
WATER
SEPARATOR
TO CONTACT
BASIN
CONTROLLER
LEFT
RIGHT
GENERATOR
DRYING TOWERS

Figure 3. Ozone generation schematic diagram.

Three components made up each system: generator, power supply and air pretreatment. Each generator was designed to produce 1.43 kg/hr (76 lb/day) of ozone at a minimum concentration of 1 percent by weight, which provided for a maximum ozone/liquid dosage of 6 mg/l at the plant design flow of 5,680 cu m/day (1.5 mgd). The generators were "iron lung" tube type units each containing 68 tubes. The generators were water cooled using potable well water flowing at a rate of approximately 1.26 l/sec (20 gpm). Power was supplied to the generator through variable voltage transformers. A controller assembly was used to adjust the voltage from the transformer to the generator, which controls the ozone generator output. The controller was designed for manual or automatic adjustment. During the research project manual adjustments based on generator amperage readings were used.

The air pretreatment components of the ozone generation system were an air compressor, refrigerant drier and air drying towers. Air pretreatment was designed to provide particle-free dry air with a dew point of -51°C at a pressure between 41.3 k N/sq m and 103 k N/sq m (6 and 15 psig). During the research project, the air pretreatment pressure was maintained at 51.6 k N/sq m (7.5 psig).

Ambient air was compressed to 51.6 k N/sq m (7.5 psig) by a Nash Model L3 water ring compressor. The compressor operates at a constant speed and had an output of about 160 cu m/hr (94 scfm). The standard conditions used throughout this report are one atmosphere pressure and 25°C temperature. A baffle separator was provided to separate the water and air. A bleed-off air valve was provided downstream of the baffle separator. The bleed-off valve at this point was determined to be necessary during the research project to enable the air flow rate to the drying towers to be controlled to prevent overloading of these units.

Compressed air was cooled to between 3.3°C and 5.6°C in a Zeks, Model 9J refrigerant drier, in order to remove excess moisture in the air. The unit was designed so that the air dew point leaving this unit did not exceed 8.9°C. Refrigerant dried air was further dewatered to a dew point less than -51°C in a Kemp Model 100 UEA-1 absorptive drier. The drier used molecular sieves and activated alumina as absorptive material. Dual towers were provided for continuous operation. Tower operation was cycled at 8-hour intervals to provide regeneration of one tower while the other was in use. Each tower was rated by the manufacturer at 131 cu m/hr (78 scfm) air flow.

The ozone contact basin was located adjacent to the mixed media filters in the main control building. The ozone generation units were located on a mezzanine above the contact basin. The ozone contact basin was 1.30 m (4.25 ft) wide, 11.6 m (38.0 ft) long and 3.66 m (12 ft) deep, which would give an ozone contact time of 14 min at 5,680 cu m/day (1.5 mgd) design flow. The first 8.22 m (27 ft) of the ozone basin was divided into nine equal sized compartments with U.P.V.C. baffles. The baffles were placed to allow vertical, serpentine flow of effluent through the basin. A schematic of the contact basin is shown in Figure 4.

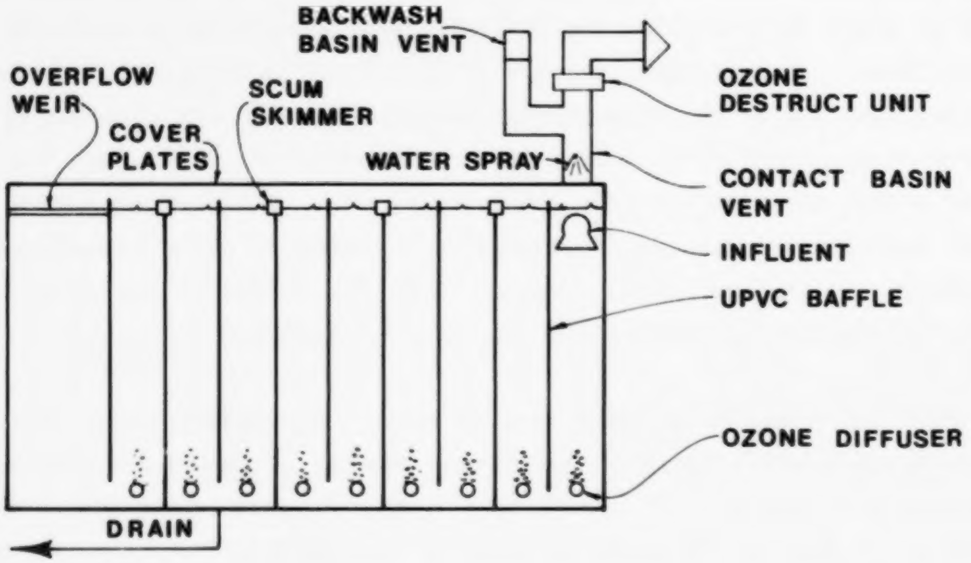

BACKWASH
BASIN VENT
OVERFLOW
WEIR
SCUM
SKIMMER
COVER
PLATES
WATER SPRAY
OZONE
DESTRUCT UNIT
CONTACT BASIN
VENT
INFLUENT
UPVC BAFFLE
OZONE DIFFUSER
DRAIN

Figure 4. Ozone contact basin schematic diagram.

Treated water from the ozone basin passed over a weir and into the backwash water storage basin where it is used for backwashing the mixed media filters. The ozone contact basin and the backwash water storage basin share a common air space above their respective water surfaces due to the described overflow weir arrangement.

The contact basin was covered with aluminum plates which were bolted in place. Hypalon gasket material was placed beneath all joints. Additionally, silicone sealant was used to cover all exposed joints. Ozone laden off-gas from both the contact and backwash water storage basins was discharged through a roof mounted exhaust fan. The fan provided a negative pressure (about 0.64 cm of water) in each basin so as to prevent ozone leakage into the main control building and/or offices. A water spray nozzle was located in the vent duct above the ozone basin tank cover to prevent foam from blocking the exhaust air flow.

Ozone was injected into the effluent in the contact basin through porous stone diffusers. The diffusers were Kullendite, Model FAO 50 as manufactured by Ferro Corporation. The diffusers were located in each of the nine baffled areas. Each diffuser was 6.4 cm (2-1/2 in) in diameter and 61 cm (24 in) long, and had an air permeability between 1.42 and 1.78 cu m/min/sq m/cm (12 and 15 scfm/ft^2/in) and a maximum pore diameter of 140 microns. Distribution piping consisted of Type 304 Schedule 40 stainless steel piping with welded and threaded joints. Distribution of ozone to each compartment was controlled by nine individual valves. Both the diffusers and distribution piping represented modifications of the original equipment.

Four adjustable height weir scum skimmers were located along the length of the ozone contact basin to facilitate removal of any scum that may be generated as a byproduct of ozonation. Scum removed by the skimmers can be pumped to the head of the plant for recycle, or pumped to the secondary clarifiers.

An ozone off-gas destruct unit is shown in Figure 4. The unit was a heat/catalyst ozone destruct system which was installed after the data collection phase of the project was completed. The ozone destruct unit represented a major design modification, which will be further discussed. The ozone destruct system was designed by Emery Industries and consisted of an off-gas heating unit, a proprietary catalyst, and an exhaust fan. The system design inlet flow rate was 5.6 cu m/min (200 scfm) and the inlet temperature was 5°C. The heating system was capable of elevating the temperature of this volume of the off-gas to a maximum value of 149°C (300°F). At this maximum temperature the heat-catalyst system was designed to discharge a very low maximum residual ozone concentration of 0.1 ppm (vol) when the heat/catalyst inlet ozone concentration was 3,000 ppm (wt) or lower. At this heating requirement, the system was designed with a variable heating system and normal system operation called for an operating temperature of 71°C (160°F). At this temperature the system, was designed to discharge a maximum residual ozone concentration of 1.0 ppm (vol) when the inlet ozone concentration was 3,000 ppm (wt) or lower. At this normal operation heating requirement, the power consumption for the system would be 7.5 kW for heating plus 0.5 kW for the exhaust fan.

SLUDGE HANDLING

The sludge handling system consisted of two aerobic digesters, one pressure roller filter, and one sludge hauling vehicle. The digesters were used for sludge holding, digestion and partial thickening. The pressure roller filter was used for further sludge dewatering prior to ultimate disposal. The sludge hauling truck was used to transport the thickened sludge to the ultimate disposal site.

Sludge Treatment

Sludge treatment was provided by aerobic digesters, which included the digester basins, oxygen transfer and basin mixing, supernatant removal and sludge removal systems. A summary of the characteristics of the aerobic digestion system is presented in Table 10.

TABLE 10. AEROBIC DIGESTER CHARACTERISTICS

Characteristic	Description
- Aerobic Digester Basins	
Number	2
Surface Dimensions (each)	63 ft x 31 ft
Sidewater Depth (each)	17 ft
Capacity (each)	246,000 gal
- Turbine Mixers	
Number (per basin)	2
Size	25 hp
- Air Blowers*	
Number	3
Capacity (each)	1200 scfm
Size	75 hp

ft x 0.035 = m; gal x 3.785 = l; hp x 0.746 = kW; cfm x 0.028 = cu m/min
*Blowers also used for aeration basin oxygen supply.

The aerobic digesters received waste sludge and scum from the secondary clarifiers. Two digester basins were provided, and could be operated in series or in parallel. Oxygen supply and basin mixing were provided by a submerged turbine aeration system, which were identical to the system provided in the activated sludge aeration basins.

Each basin had supernatant and sludge removal capability. Supernatant removal was used to partially thicken the digested sludge and to improve the performance of the digestion process and the sludge dewatering pressure roller filter. Supernatant flow was directed to the Thompson River Lift Station where it was pumped to the flow equalization basin and recycled back through the plant. The sludge removal piping was located beneath the floor of the basins and was used to transport sludge to the pressure roller filter. These lines could also be used to drain the basin contents back to the Thompson River Lift Station.

Sludge Dewatering and Disposal

Digested sludge was dewatered prior to ultimate disposal with a Smith and Loveless Model 40-1 pressure roller filter. The pressure roller filter system consisted of a sludge conditioning unit (sludge feed pump, polymer mix tank and metering pump, flash mixer and flocculator), and a sludge dewatering unit (primary and secondary screens, spray cleaning jets, transition chutes, and three double pressure rollers), and a sludge transportation unit (conveyer belt from dewatering unit to sludge hauling vehicle). Dewatered sludge was hauled to the disposal site with a covered dump truck, which had a modified dump body so that it was watertight. A summary of the characteristics of the pressure roller filter and sludge hauling truck is given in Table 11.

TABLE 11. PRESSURE ROLLER FILTER AND SLUDGE HAULING TRUCK CHARACTERISTICS

Characteristic	Description
- Sludge Conditioning Equipment	
Sludge Feed Pump	
Type	Variable speed, diaphragm pump
Capacity	0 - 40 gpm
Polymer Mix Tank	
Type	Fiberglass
Volume	250 gal
Polymer Feed Pump	
Type	Variable speed gear pump
Capacity	0 - 1.5 gpm
Flash Mix	
Tank Size	12 in Dia. x 42 in long (21 gal)
Mixer Drive	0.5 hp (variable speed)
Flocculator	
Tank Size	48 in x 24 in x 46 in (230 gal)
Flow Pattern	Horizontal Serpentine Flow
Paddle Drive	0.5 hp (variable speed)
- Sludge Dewatering	
Primary Stage	
Screen Type	Endless, mono-filament open mesh
Screen Size	40 in wide x 46 in long
Secondary Stage	
Screen Type	Endless, mono-filament open mesh
Screen Size	40 in wide x 48 in long
Pressure Rollers	3 sets with variable pressure adjustment
Transportation Stage	
Conveyer Belt Size	16 in wide x 24 ft long
- Sludge Hauling	
Vehicle Type	Covered watertight dump truck
Capacity	7 cu yd

gpm x 0.063 = l/sec; gal x 3.785 = l; in x 2.54 = cm; hp x 0.746 = kW; ft x 0.305 = m; cu yd x 0.765 = cu m.

Sludge from the digester was pumped at a controlled rate to the sludge conditioning system. Polymer addition involved the injection of a stream of polymer solution into the sludge feed line. The mixture of polymer and sludge then entered a flash mixer where rapid mixing dispersed the polymer throughout the sludge particles. A flocculator followed the flash mixer, and the mechanism provided a plug flow condition together with gentle agitation. The conditioned sludge then entered the primary stage of the sludge dewatering segment of the system.

The primary stage of the dewatering unit consisted of an endless, horizontal, open-mesh screen which traveled around two rollers. A third roller was located midway between the two end rollers and resulted in a slightly elevated portion of the screen. As the conditioned sludge moved onto the primary screen, the free water drained away and the flocculated sludge particles were trapped on the screen. Further release of water was obtained by passing the sludge over the elevated roller. At the end of the primary stage the sludge was transferred to the secondary stage of the dewatering unit. A jet spray bar located above the returning portion of the primary screen cleaned entrapped sludge particles from the screen mesh. The filtrate from the primary stage, which consisted of the released water, non-captured sludge, and spray water, collected in a drain located below the primary screen.

Sludge from the primary stage was transferred to the secondary stage where it was deposited onto a screen identical to the primary screen. Three sets of pressure rollers were located along the secondary screen, each set having one roller above and one roller below the upper portion of the screen. As the sludge moved from one set of rollers to the next, progressively higher pressure was applied to the sludge. With this arrangement water was squeezed from the sludge three times before leaving the dewatering unit. The resulting sludge cake dropped to a conveyor system where it was transported to a truck. Similar to the primary screen, the secondary screen had a jet spray bar to clean the sludge particles trapped in the screen mesh. Released water, non-captured sludge, and spray water from the secondary stage were collected in a drain and together with the primary filtrate flowed back to the Thompson River Lift Station then back through the plant.

The conveyer system that transported dewatered sludge to the sludge hauling truck was equipped with a scraper that cleaned the conveyer belt prior to its return cycle. The sludge hauling truck was a covered dump truck that was modified so that the tailgate was watertight. Also, special gate latch hooks were provided to prevent the gate from accidently opening during transport to the disposl site. Two sludge disposal sites were utilized, the community sanitary landfill and community park areas that were being reclaimed.

MISCELLANEOUS FACILITIES

Stand-by Power

The plant and lift stations were provided three different power sources: Big Thompson loop power and South loop via the Estes Park substation, and two stand-by generators (one at the plant and one at the Fish Creek Lift Station). The power supply automatically switched to the other power loop when one of the two power loops failed. Each power loop could supply the plant with its full operating power requirement. If both power loops fail, the stand-by generators automatically start. The plant standby generator was a 625 kva diesel fuel powered unit and provided the plant with only part of its full power requirement. It had the capability of operating the Thompson River Lift Station, one aeration blower, the return sludge pumps, the ozone generation system, and other supporting equipment to provide a minimum of secondary treatment and disinfection. The Fish Creek Lift Station stand-by generator was a 125 kva diesel fuel powered unit and could operate all the pumps in the lift station.

Plant Laboratory

The laboratory at the UTSD plant was expanded and equipped to conduct all standard microbiological and wet chemistry analyses conducted during the research effort. The analyses that were conducted are summarized in Appendices A through F. The laboratory was located in the main plant building in a 9.9 m (32.5 ft) by 4.1 m (13.5 ft) room with total counter length of 13.7 m (45 ft).

Potable and Non-Potable Water Supply

The plant was designed with its own potable water supply system. The system included a shallow well located near the plant site, a chlorination unit, a pressurized storage tank, and a pumping system. The well was located near the Thompson River Lift Station and the chlorination unit and pumping system was located in the lift station dry-well. Potable water was supplied to the plant laboratory, restrooms, ozone generation system, filter control system, and raw sewage pumps. The system was capable of supplying 2.5 l/sec (40 gpm) of potable water at 413 k N/sq m (60 psig) pressure.

The plant non-potable water supply system was ozone contact basin effluent, and was used for plant washdown and outside irrigation. The system consisted of a pressurized storage tank and a pumping system. The system is capable of supplying 6.3 l/sec (100 gpm) of non-potable at 461 k N/sq m (67 psig) pressure.

SECTION 6

DATA COLLECTION PROCEDURES

To evaluate the individual unit processes at the UTSD facility an extensive sample collection and analysis schedule was implemented. However, the laboratory was only partially functional from plant start-up in March 1976 until October, 1976, due to equipment delivery delays and other start-up problems. A limited analytical schedule was followed using the M & I, Inc. laboratory located in Fort Collins, Colorado until the full analytical schedule was implemented at the UTSD laboratory. As closely as possible a similar sample collection and analysis schedule was maintained throughout the project. However, some modifications were necessary in order to allow for special testing to be completed on various unit processes and to conduct quality control checks.

Analytical Procedures and Quality Control

The procedures used for data analysis during the research project were Standard Methods and/or EPA procedures with minor modifications. A listing of the specific procedures for each analysis and description of the modifications used is presented in Table 12.

TABLE 12. DESCRIPTION OF ANALYTICAL PROCEDURES IMPLEMENTED DURING RESEARCH PROJECT

Analysis	Procedure	Comment
BOD_5	Std. Methods, p. 543*	Samples not seeded; in-bottle dilutions made, 2 dilutions per sample run; same bottle initial and final D.O.'s made using an electronic D.O. meter.
COD	Std. Methods, P.550-554.	20 ml aliquots used; standards of potassium hydrogen phthalate run with each set.
TSS	Std. Methods, p.94.	Gooch crucibles and glass fiber filters used.
TKN	EPA Manual, p.159-163**	Micro procedure used; titrimetric or Nessler finish used as necessary; Standard solutions of glutamic acid run with each set.
NH_4-N	EPA Manual, p.175-181	Micro procedure used; titrimetric or Nessler finish used as necessary; Standard solutions of ammonium chloride run with each set.
NO_2&NO_3-N	EPA Manual, p.201-206	10.0 mg/l of NO_3-N used instead of 1.0 mg/l to achieve complete activation of cadmium-copper column. This alteration assured constant color development. Standard solutions run with each set.
Total P	EPA Manual, p.251-255	Persulfate digestion used; digested samples neutralized with sodium hydroxide to phenophthalien pink color (not to metered pH 7) then 5N sulfuric acid added until pink color dissipated; standard solutions run with each set.
Alkalinity	Std.Methods, p.278-282	Potentiometric titration to pH 4.5; Tris (Hydroxymethyl) aminomethane used to standardize sulfuric acid titrant.
pH	---	Orion 701 digital pH meter, calibrated at pH 4 and pH 7 before each set of measurements.

(continued)

TABLE 12. (Continued)

Analysis	Procedure	Comment
D.O.	----	YSI Model 54RC electronic oxygen meter with field and BOD probe air calibrated prior to each set of measurements.
Coliform	Std.Methods, p.922-925; 928-935 and 937-939	MPN analysis used on ozonated samples; membrane filter technique used on other samples; two or more dilutions run on each sample.

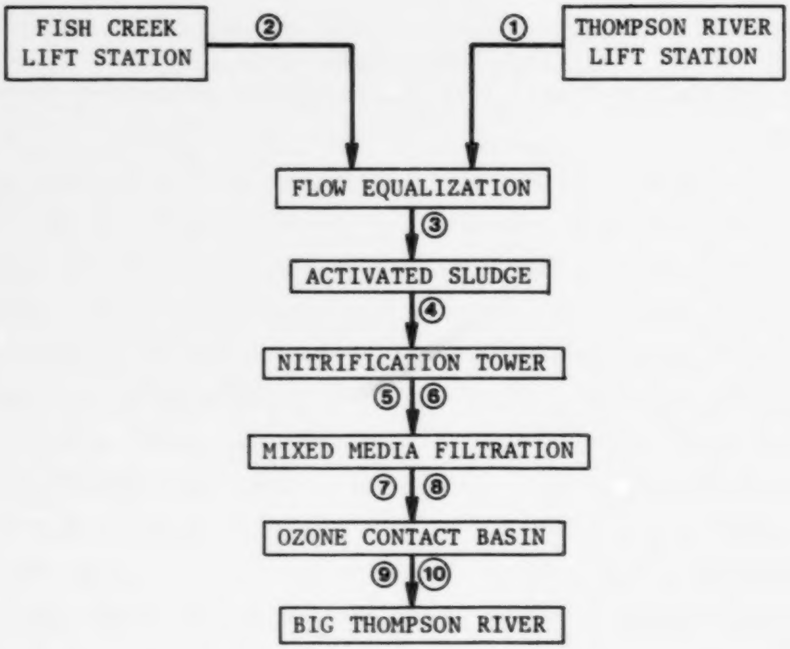
*Standard Methods 14th ed., 1975, APHA, AWWA, WPCF.
**Methods for Chemical Analysis, 1972, Environmental Protection Agency.

The routine analytical schedule incorporated several quality control aspects. Routine maintenance, cleaning and calibration of all instruments was conducted. Also, modifications were made to some equipment to reach the required performance level (i.e., special high altitude operating pressure gauge for the autoclave and special pretreatment of influent to the distilled water system). Class A, borosilicate glassware was used for volumetric measurements and was washed with lab detergent, rinsed with tap water, rinsed with distilled water and air dried; or acid cleaned, rinsed with distilled water, and air dried. ACS reagent grade chemicals and high quality distilled water (specific conductance less than 5 micromhos/cm) were used to make all reagents, except for Nesslers reagent which was purchased commercially. Routine duplicate analyses and standard samples, where applicable, were conducted on at least 10% of all analyses. Special microbiological samples were analyzed by three laboratories: the UTSD lab, the M & I lab and the Water Quality lab at Colorado State University. The quality control checks conducted on all duplicate, standard, and split samples indicated that satisfactory techniques were implemented and maintained at the UTSD lab.

All raw data were developed using bench cards and calculations were double checked before recording the results on the weekly data sheets. Weekly averages of the data were then computed and were recorded on data summary sheets. The weekly average results for each unit process are presented in process sequence from Appendix A through Appendix F and serve as the basis for the data evaluations made in this report.

Analytical Schedule and Sample Type and Collection Frequency

To aid in sample identification and analysis, the mainstream sampling stations were numbered as shown in Figure 5.


FISH CREEK LIFT STATION
②
①
THOMPSON RIVER LIFT STATION
FLOW EQUALIZATION
③
ACTIVATED SLUDGE
④
NITRIFICATION TOWER
⑤
⑥
MIXED MEDIA FILTRATION
⑦
⑧
OZONE CONTACT BASIN
⑨
⑩
BIG THOMPSON RIVER

*Note 5 = Sample when Redwood Media was used.
6 = Sample when Dumped Plastic Media was used.
7 = Sample during denitrification special study.
8 = Sample during normal operation.

Figure 5. Mainstream sampling stations during the research project.

During the course of the research project some sample points were deleted and others were activated during the different evaluation periods. Sample station No. 2 (Fish Creek Lift Station) was not sampled because of its remote location and because the flow from this lift station represented less than 10% of the flow to the plant. Sample station No. 5 (Nitrification tower effluent - Redwood media) and sample station No. 6 (Nitrification tower effluent - Dumped media) were used correspondingly when each of the different media types were evaluated. Sample station No. 7 (Mixed-media Filter - Denitrification effluent) was activated only during the methanol addition/denitrification phase of the research effort. During all other times of the project sample station No. 8 (Mixed media filter effluent) was used. Sample station No. 3 (Flow equalization basin effluent), station No. 4 (Activated sludge effluent) and station No. 9 (Ozone contact basin effluent) were used throughout the research project. Sample station No. 10 was not used for the routine research project results.

Different types of samples were collected depending on the nature of the parameter analyzed. Grab samples and/or in-situ measurements were used for dissolved oxygen, pH, fecal coliform, total coliform and temperature measurements. Composite samples were collected for the BOD_5, COD, TSS, TKN-N, NH_4-N, NO_2&NO_3-N, Total P and alkalinity measurements. The composite samples were collected both automatically and manually. Two refrigerated automatic samples (Isco Model 1580R) were used to collect the samples at sample station No. 1 (Thompson River Lift Station Influent) and station No. 3 (Flow Equalization Basin Effluent). The automatic sampler at station No. 1 collected the samples proportional to flow through operation according to the number of lift station pump cycles. The sampler at station No. 3 collected equal volume samples every 2 hours, and since the flow rate from the equalization basin was controlled at a constant rate throughout the day the sample was collected proportional to flow. The daily composite samples were collected manually at all other sample stations. During the first four months of the research project (June 1976-September 1976) composite samples were collected for a period of 8 hours to 16 hours each day. During the remaining twenty-two month data collection phase of the project, equal volume samples were collected at 2-hour intervals for a 24-hour period. Because the flow rate through the plant was controlled at a constant rate, the composited equal volume samples were proportional to flow.

Composite samples were collected on Sunday through Thursday and were analyzed Monday through Friday. Grab samples were collected Monday through Friday. The analytical schedule that was followed is shown in Table 13.

TABLE 13. ANALYTICAL SCHEDULE FOR THE MAINSTREAM SAMPLES

Analysis	Frequency	Sample Type	Sample Station*
TSS	5/wk	Composite	1, 3, 4, 5 or 6, 7 or 8, 9
COD	"	"	"
TKN-N	"	"	"
NH_4-N	"	"	"
NO_2&NO_3-N	"	"	"
Total P	"	"	"
Alk	"	"	5 or 6, 9
Alk	2/wk	"	1, 3, 4, 7 or 8
BOD_5	2/wk	"	1, 3, 4, 5 or 6, 7 or 8,
Coliform (Tot. & Fecal)	2/wk	Grab	1, 3, 4, 5 or 6, 7 or 8, 9
Coliform (Tot. & Fecal)	5/wk	Grab	7 or 8, 9
D.O.	5/wk	in-situ	1, 3, 4, 5 or 6, 7 or 8, 9
pH	5/wk	Grab	1, 3, 4, 5 or 6, 7 or 8, 9
Temp	5/wk	in-situ	1, 3, 4, 5 or 6, 7 or 8, 9

*1. Thompson River Lift Station Influent.
3. Flow Equalization Basin Effluent.
4. Activated Sludge Clarifier Effluent.
5 or 6. Nitrification Tower Effluent - Redwood or Dumped Plastic Media.
7 or 8. Mixed Media Filter Effluent - Denitrification Phase or Normal Phase.
9. Ozone Contact Basin Effluent.

In October 1977, the analytical frequency for Total P and for COD was reduced to 2 and 3 times per week, respectively, based on an analysis of the 5-times per week results. The analysis was made for one week of each month for a 10-month period from December 1976 to September 1977. The analysis of the COD results compared the data for 5 days to data for 3 days within the same week. On the average these values were within 1.5 percent of each other.

Similarily, comparing the weekly results of Total P for the 5 days of analysis to 2 days of results showed that on the average these values were within 2.0 percent of each other. Reducing the analytical schedule enabled the staff to devote laboratory time to special testing, yet it did not adversely affect the results of the data collected.

In addition to analyses of the wastewater, various analyses of the in-plant sidestreams were conducted periodically. The analyses were conducted on grab samples of waste sludge, aerobic digester supernatant, aerobic digester sludge, dewatered sludge, activated sludge mixed liquor, backwash wastewater, sludge dewatering recycle, and river samples. The various analyses conducted included BOD_5, TSS. D.O., pH, TKN, NO_2&NO_3-N, NH_4-N, Total P, COD, ALK, Total Coliform, Fecal Coliform, SVI, and VSS.

SECTION 7

RESULTS AND DISCUSSION

GENERAL

Data required for the evaluation of the overall performance, cost and design aspects of the UTSD treatment system and for each of the individual unit processes was collected for a 105-week period. The effluent from the individual unit processes was not sampled during the initial and final portions of this 105-week data collection period. Initial laboratory start-up problems postponed some individual unit process analyses for three months until 10/3/76. During the final portion (i.e., last two months) of the data collection effort, special testing for the ozone and denitrification systems was accomplished in place of sampling and analyzing all of the unit processes. Thus, of the 105 weeks during which overall performance information was collected, data was collected on a routine basis for the individual unit processes for an 88-week period. During June 1977, the activated sludge process was removed from service to provide modifications to the gates between the two aeration basins and the two aerobic digesters. No data was collected during this period.

In this section of the report the evaluation of individual unit processes is presented as they occur in the plant flow schematic, beginning with the flow equalization process. Also presented are the results of separate special studies conducted on the denitrification, ozonation and sludge dewatering systems. Finally, an overall evaluation of all processes is presented.

FLOW EQUALIZATION

The flow equalization process was used to control the wastewater flow rate and the recycle flow rates through the UTSD plant. Wastewater was pumped to the basin from both lift stations, and a controlled rate of flow was discharged from the basin. (All in-plant recycle streams were returned to the Thompson River Lift Station). The liquid volume in the basin would typically increase during the day and decrease during the night, corresponding to wastewater flow variations. The equalization basin was not equipped with an aeration or mixing system to keep solids in suspension, although structural provisions were made if operating conditions warranted oxygen addition and/or mixing. As designed, however, settleable solids entering the basin would settle to the bottom of the basin and were then scraped to the center of the basin where the discharge pipe was located. Provisions to handle the organic variations in loading associated with this arrangement were provided in downstream systems.

These aspects of the flow equalization process that were evaluated included:

a) Affects of minimal mixing and no oxygen addition.
b) Characteristics of influent and effluent.
c) System operations and maintenance requirements.
d) Performance with respect to hydraulic dampening capability.

Since minimal mixing and no oxygen addition were provided the possibility of low D.O. conditions and odor problems existed. The basin influent and effluent D.O. concentrations were measured daily for a one-year time period. Figure 6 shows the 4-week average D.O. results throughout the period of investigation. As shown, the fall, winter and spring influent and effluent D.O. concentrations were above 1 mg/l. The summer effluent D.O. concentrations were minimal (0.1 mg/l), but no odor problems were experienced. The relatively high D.O. concentrations during the colder periods of the year were attributed to the relatively cold wastewater temperature (5°C to 6°C in the winter) and resulting reduced biological activity in the equalization basin. The

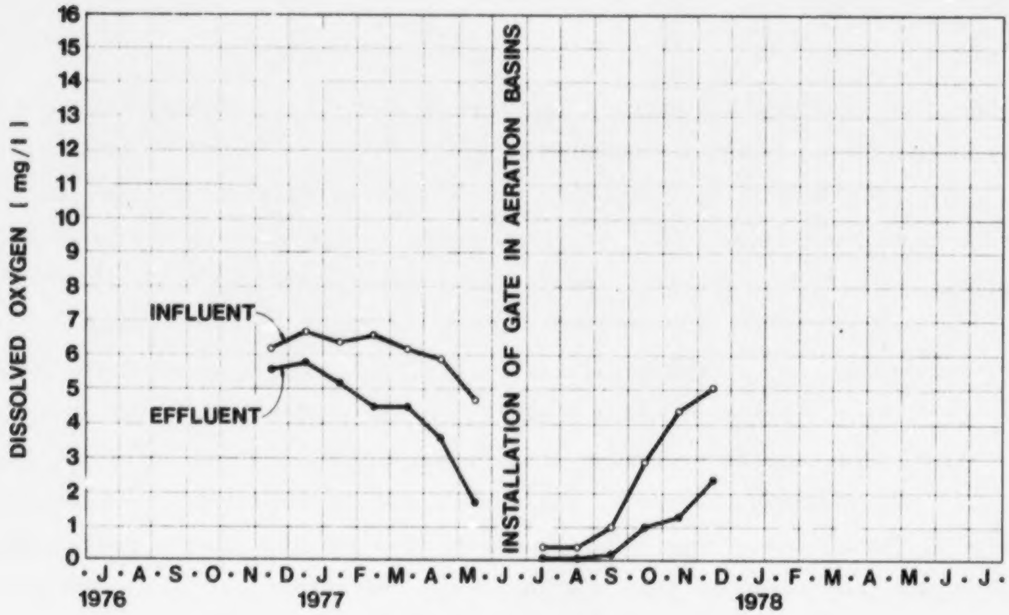


Figure 6. Flow equalization basin influent and effluent dissolved oxygen concentration.

lower D.O. concentration in the summer was attributed to a higher wastewater temperature of about 18°C., which affected both the soluability of oxygen as well as increasing the biological activity. The absence of odors during the summer was partially due to shorter basin detention times associated with higher summertime flow rates. The basin detention time at one-half plant design flow of 2,840 cu m/day (0.75 mgd) and at a basin level of 1.8 m (6 ft) is 5.2 hr. During the summer a flow of 2,840 cu m/day (0.75 mgd) was reached and often exceeded. Another major reason for minimal odors during the summer was attributed to the fact that the settleable organic material in the wastewater was removed from the basin shortly after it entered, much more rapidly than the average hydraulic detention time indicates. Thus, these solids were not available to contribute to the biological activity which could produce odors.

Other than a change in the D.O. concentration, no significant chemical or biological changes in wastewater characteristics occurred within the flow equalization basin. A summary of results of various parameters analyzed in the basin influent and effluent is shown in Table 14.

TABLE 14. SUMMARY OF FLOW EQUALIZATION BASIN INFLUENT AND EFFLUENT CHEMICAL AND MICROBIOLOGICAL QUALITY*

Parameter	Basin Influent (X_1)	Basin Effluent (X_2)	Percent Difference $\left(\frac{X_1-X_2}{X_2} \times 100\right)$
BOD_5 (mg/l)	218	213	2.3
TSS (mg/l)	200	180	11.1
COD (mg/l)	351	330	6.4
TKN (mg/l)	20.6	22.4	-8.0
NH_4-N (mg/l)	12.6	12.9	-2.3
Alk as $CaCO_3$	109	108	0.8
Total P (mg/l)	5.5	5.8	-5.2
Dissolved Oxygen (mg/l)	4.1	2.6	57.6
Total Coliform**	4.0×10^6/100 ml	4.6×10^6/100 ml	-13.0
Fecal Coliform**	1.1×10^6/100 ml	1.1×10^6/100 ml	0

*Summary of data from 11/28/76 to 12/24/77.
**Geometric Mean.

For all parameters analyzed except dissolved oxygen and total coliform, the percent difference between influent and effluent ranged from -8.0 percent to 11.1 percent. These differences are felt to be within accepted sampling and/or testing accuracy. The total coliform difference was -13 percent, but the fecal coliform difference was negligible. The difference in D.O. concentration was 58 percent. This change was attributed to biological activity within the basin, but as mentioned earlier did not result in any odor problems. The flow equalization process was evaluated for one full year of the two-year data collection phase of the research project. Data collection was then stopped because chemical and microbiological changes through the basin did not appear to be significant, and it was felt that more time could be devoted to data collection for special studies and other process evaluations.

The equalization basin was rectangular in shape and had an overflow sidewater depth of 3.66 m (12 ft). The total basin volume was 1,230 cu m (325,440 gal). Typically, the basin operated between fill depths of 0.91 m and 2.7 m (3 ft and 9 ft). At the flow rates experienced during the research project no problems were encountered with basin capacity respective to sufficient storage volume for flow equalization. However, daily average flows ranged from 15 to 67 percent of design plant flows. The flow rate from the equalization basin was measured by a magnetic flow measuring instrument (mag meter). The signal from the mag meter was used to indicate and totalize the flow rate and also was used to activate the flow control equipment. The mag meter signal was sent to a controller assembly where it was compared to a set rate value that was "dialed" in by the operators. The controller would then open or close a "pinch valve" to increase or decrease the basin effluent flow rate as called for. This system, when functioning, controlled the flow rate from the basin to ±2 percent from the set rate which resulted in excellent dampening of the hydraulic flow.

Some problems were experienced with the flow equalization process, mainly in the area of flow measurement and control which prevented the system's use on a continuous basis. Problems included calibration difficulties with the mag meter and problems with the mechanism that opened or closed the pinch valve. The mag-meter was difficult to calibrate due to the lower than design flows that were received at the plant. The meter was especially difficult to calibrate when flow rates were only about 20 to 30 percent of design values. The pneumatically driven arm that opened and closed the pinch valve had to be pinched down quite substantially. This situation was believed to have contributed to occasions of improper valve functioning. Unlike the downstream processes, the mag meter and flow control valve were not provided as parallel trains and therefore were sized based on total plant design flow. During the time the pinch valve assembly and mag meter were non-functional an alternative method of flow control was implemented. This alternative method consisted of making routine adjustments to a plug valve located on the basin effluent line. The plant flow variation using this method of control was approximately ±15 percent of the desired flow rate. It is anticipated that these operational problems should occur less frequently as flow increases, and that future difficulties will be easier to correct and/or prevent since the operators have gained more experience with the system.

During the flow equalization evaluation period a grease build-up of about 13 mm to 25 mm (0.5 in to 1 in) occurred on the basin walls. This build- up did not result in any odor problems and did not present an aesthetic problem since the basin was covered. Periodic basin cleaning at 3-month intervals prevented excessive grease build-up. An operational problem was encountered when the scraper mechanism motor burned out. With the scraper not operating, slug loads of settleable solids were directed to the activated sludge basins when the basin was drained down. Flow equalization had to be halted until the motor was repaired.

GRIT REMOVAL

The grit removal system for the UTSD system was designed with a great deal of flexibility to facilitate grit and grease removal. Because the collection system was new, very little grit was received at the plant site. Air was supplied to the grit basin to aid in grease floatation. However, very little grease accumulated in the grit basin. As mentioned, most of the grease accumulated within the flow equalization basin. Within the grit removal building slight odors could at times be detected, but no serious odor problems ever developed. In general, the grit removal process performed in a very satisfactory manner.

ACTIVATED SLUDGE

The activated sludge treatment process directly followed the flow equalization and grit removal systems. With this arrangement all flow to the activated sludge process was equalized prior to entry to the process. However, the organic solids loading was not equalized because of the design characteristics of the flow equalization system. Because of the flow equalization design and the fact that no primary clarifiers were provided, all settleable solids that were received at the plant were received in the activated sludge aeration basins and eventually were wasted from the secondary clarifier. This arrangement caused the organic loading to the system to be quite variable within a day.

Seasonal variations in hydraulic and organic load occurred because the plant served a summertime tourist oriented community. The flow to the plant during the research project is graphically illustrated in Figure 7. The plant organic load as represented by BOD_5 is depicted in Figure 8. Flow to the plant during the summer of 1976 was lower than the following tourist seasons because of the Big Thompson flood disaster on July 31, 1976, which significantly reduced the community's tourist trade. The peak tourist season lasts about 3 months: June, July and August. During that time the flow to the plant was about 134 percent greater than the design flow. (Note: half plant design values are used for design flow because only half of the activated sludge units were in service). The BOD_5 loading during these peak flow periods was as much as 228 percent of design values. However, during the rest of the year the wastewater flow and BOD_5 loading averaged about 50 percent of design values.

The lower BOD_5 loadings during the winter, non-tourist season were caused by lower wastewater flows coupled with relatively low BOD_5 concentration of about 100 mg/l to 150 mg/l. (See weekly data values presented in Appendix B). These lower BOD_5 concentrations were attributed to "bleeder" water. Bleeder water refers to tap water that is run continuously to keep water lines from freezing. This approach is used frequently at high altitudes where deep ground frost is common and where dwellings are not occupied full time. The significantly higher BOD_5 loadings during the summer tourist season were caused by higher wastewater flows coupled with much higher BOD_5 concentrations of 250 mg/l to 400 mg/l. The higher BOD_5 concentrations during the summer were partially attributed to a small volume, high strength waste discharged into the UTSD collection system through a septic tank and

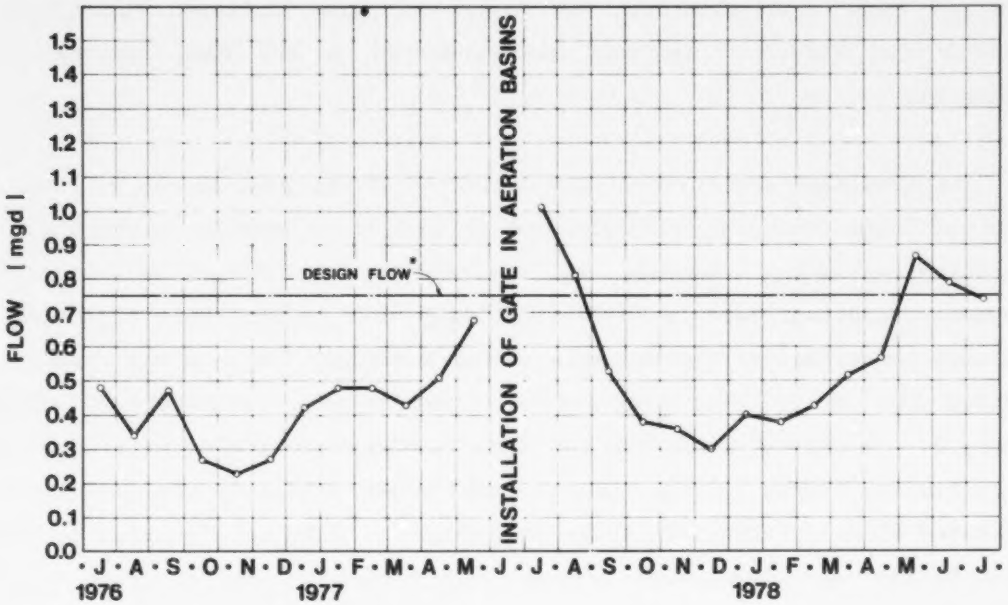


Figure 7. Plant influent wastewater flow rate during the research project. (mgd x 3785 = cum/day)

* Design flow for 1/2 of the activated sludge process in service.

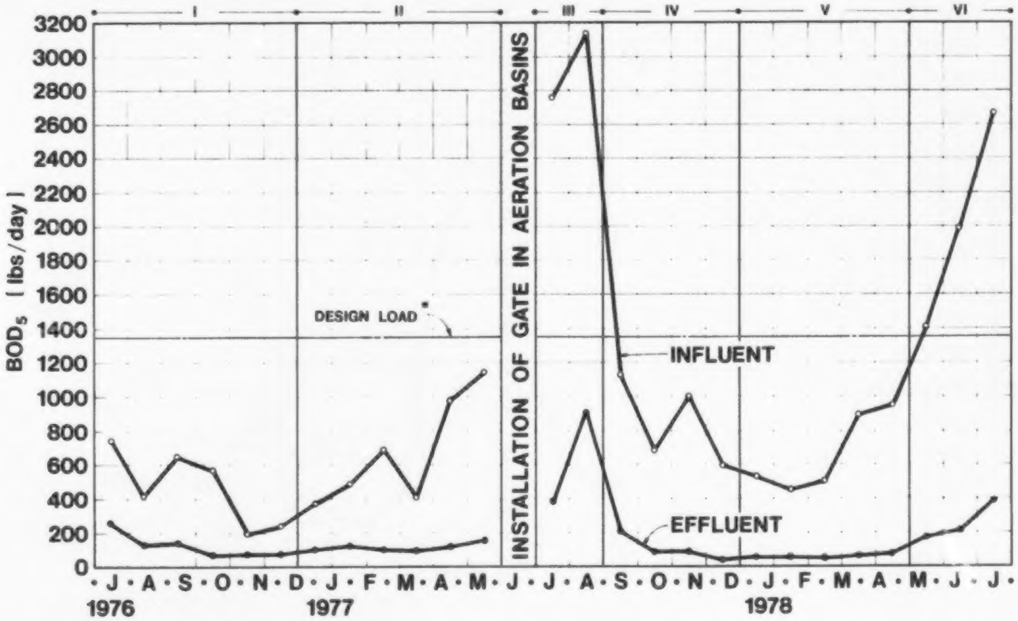


Figure 8. Activated sludge influent BOD$_5$ loading and effluent BOD$_5$ residual (lb/day x 0.454 = Kg/day)
*Design loading for 1/2 of the activated sludge process in service.

chemical vault dump station. As such, the flow variation throughout the project (See Figure 7) was not as pronounced as the BOD_5 loading. (See Figure 8).

The treatment objective of the activated sludge process was to reduce the plant effluent BOD_5 concentration and to facilitate ammonia oxidation in the nitrification tower. However, the variable organic content of the influent played an important part in the system being able to meet this objective. To evaluate the effect of the variable system loadings, the research results were divided into six different operational time periods (I to VI) as shown in Figure 8. In Period I and IV, low BOD_5 loadings encouraged nitrification in the activated sludge system. The influent ammonia loading and ammonia in the activated sludge effluent is shown in Figure 9. This data is also subdivided into the six operational time periods. In Period III and VI, extremely high BOD_5 loadings for relatively short periods of time caused excessive amounts

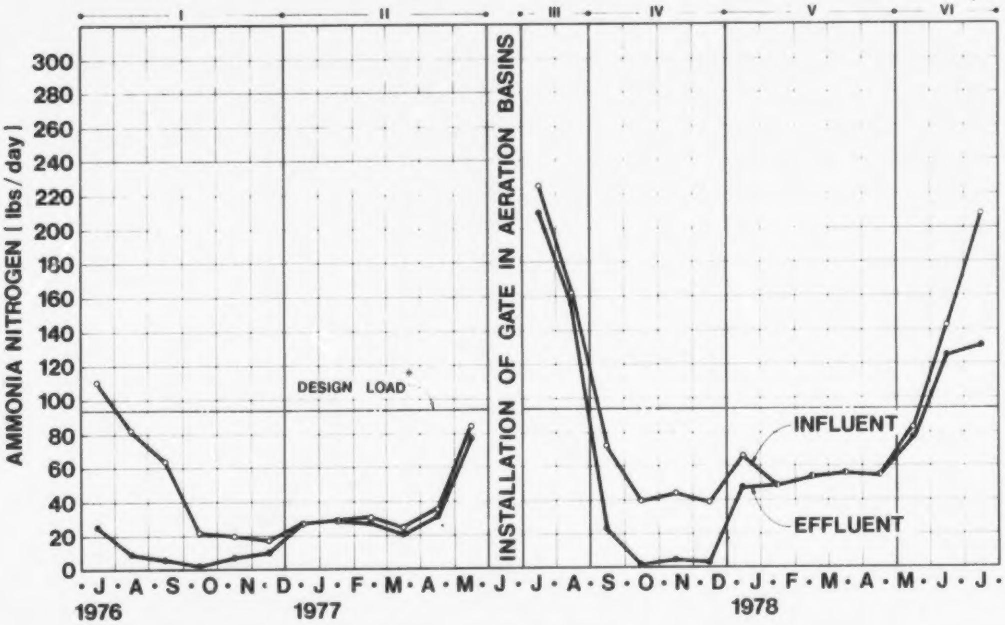


Figure 9. Activated sludge influent ammonia loading and ammonia residual (lb/day x 0.454 = Kg/day).
*Design Ioad for 1/2 of the activated sludge process in service.

of BOD_5 in the activated sludge effluent. In Period II and V, relatively low BOD_5 loadings occurred, but a sudden change in plant BOD_5 loading coupled with extremely cold wastewater temperatures discouraged nitrification in the activated sludge system.

Period I and IV are characterized by relatively low BOD_5 loadings and a high degree of nitrification occurring in the activated sludge process. A portion of the results for Period I were omitted from discussion because of the Big Thompson flood disaster on 7/31/76. After the flood the plant was seeded with sludge from the Estes Park Sanitation District. The Estes Park plant was nitrifying, and the nitrifying seed sludge continued to convert ammonia at the UTSD plant. Nitrification during Period I continued for 20 weeks due to the relatively low BOD_5 loading to the activated sludge process. Nitrification occurred for 16 weeks during Period IV even though BOD_5 loading was higher, because of the long mean cell residence time that was maintained in the system. A summary of activated sludge performance for Period I and IV is shown in Table 15.

TABLE 15. SUMMARY OF ACTIVATED SLUDGE PERFORMANCE FOR OPERATIONAL PERIOD I AND PERIOD IV

Parameter	Period I 8/8/76 to 12/26/76	Period IV 9/4/77 to 12/25/77
Flow (mgd)	0.32	0.39
BOD_5		
Influent (mg/l)	146	260
Effluent (mg/l)	35	31
Removal (%)	76	88
TSS		
Influent (mg/l)	135	224
Effluent (mg/l)	26	30
Removal (%)	81	87
TKN		
Influent (mg/l)	21	26
Effluent (mg/l)	6.3	5.3

(Continued)

TABLE 15. (Continued)

Parameter	Period I 8/8/76 to 12/26/76 (20 weeks)	Period IV 9/4/77 to 12/25/77 (16 weeks)
NH_4-N		
Influent (mg/l)	14	15
Effluent (mg/l)	2.5	1.7
NO_2&NO_3-N		
Influent (mg/l)	0.8	0.3
Effluent (mg/l)	12	15
Alkalinity (as $CaCO_3$)		
Influent (mg/l)	84	113
Effluent (mg/l)	33	23
pH (median)		
Influent (units)	6.8	7.0
Effluent (units)	6.0	6.0
MLSS (mg/l)	1670	3730
MLVSS (mg/l)	920	2830
MCRT (days)	9	38
F/M BOD_5/MLVSS (kg/kg/day)	0.21	0.11
Organic Load (lb BOD_5/day/ 1000 ft^3)	12	27
Clarifier OFR (gpd/ft^2)	255	310

mgd x 3785 = cu m/day; lb BOD_5/day/1000 ft^3 x 16 = gm/cu m/day
gpd/ft^2 x 0.0408 = cu m/day/sq m

The average effluent ammonia concentration during Period I was 2.5 mg/l. This resulted in a very low ammonia loading to the nitrification tower. Operational controls were implemented to discourage ammonia oxidation in the activated sludge system. Increased sludge wasting was implemented to reduce the system mean cell residence time. The result was not effective in discouraging ammonia oxidation and had a negative effect on BOD_5 removal, which was only 76.0 percent. Therefore, in Period IV (one year later) no attempt was made to discourage ammonia oxidation with operational changes.

Extensive ammonia oxidation occurred (effluent ammonia concentration was 1.7 mg/l), but BOD_5 removal improved averaging 88.1 percent. The organic removal during these two operational periods was satisfactory, but high levels of ammonia oxidation affected the performance of the nitrification tower discussed in a later section.

Organic loadings to the activated sludge process were relatively low in Periods II and V; however, these periods were characterized by limited nitrification in the activated sludge process. Two factors were felt to be responsible for the limited ammonia oxidation that occurred. At the onset of each of these periods a rapid and substantial increase in both hydraulic and organic loading to the plant occurred due to a large influx of tourists during the Christmas holiday season. Wastewater temperatures typically decrease to winter time lows during this same period, also. Due to the influx of people, the BOD_5 loading increased during the start of Period II by 140 percent over the 4-week period prior to the holiday period. At the start of Period V, the BOD_5 loading similarly increased by 141 percent. This increase in BOD_5 loading and the associated increase in sludge wasting appeared to be directly associated with the decreased ammonia conversion that occurred in the activated sludge process. After the holiday periods loading returned to the pre-holiday levels but nitrification capability did not reoccur. It was felt that the low wastewater temperature of only 4°C to 5°C during most of both Period II and Period V discouraged the return of the nitrifying organisms. A summary of activated sludge performance for the entire Period II and Period V interval is shown in Table 16. The rapid changes in the hydraulic and organic loading that characterized the beginning of each of these periods, is shown in the average weekly values presented in Appendix B.

TABLE 16. SUMMARY OF ACTIVATED SLUDGE PERFORMANCE FOR OPERATIONAL PERIOD II AND PERIOD V

Parameter	Period II 12/27/76 to 6/12/77	Period V 12/25/77 to 5/14/78
Flow (mgd)	0.50	0.46
BOD_5		
Influent (mg/l)	157	169
Effluent (mg/l)	27	14
Removal (%)	83	92
TSS		
Influent (mg/l)	130	168
Effluent (mg/l)	19	17
Removal (%)	85	90
TKN		
Influent (mg/l)	16.0	23.5
Effluent (mg/l)	10.5	16.8
NH_4-N		
Influent (mg/l)	9	15
Effluent (mg/l)	8	14
NO_2&NO_3-N		
Influent (mg/l)	1.1	1.4
Effluent (mg/l)	1.8	1.5
Alkalinity (as $CaCO_3$)		
Influent (mg/l)	84	109
Effluent (mg/l)	78	104
pH (median)		
Influent (unit)	7.2	7.2
Effluent (unit)	6.8	6.8
MLSS (mg/l)	1495	3720
MLVSS (mg/l)	1170	2865
MCRT (days)	7	18
F/M, BOD_5/MLVSS (lb/lb/day)	0.28	0.09
Organic Load (lb BOD_5/day/1000 ft^3)	21	20
Clarifier OFR (gpd/ft^2)	398	366

mgd x 3785 = cu m/day; lb BOD_5/day/1000 ft^3 x 16 = gm/cu m/day; gpd/ft^2 x 0408 = cu m/day/sq m

The fact that nitrification ceased is common to both Period II and V. The abrupt halting of nitrification in the activated sludge resulted in a sudden increase in ammonia loading to the nitrification tower, which impacted tower performance as described in a late section.

Although many similarities existed between Period II and V, the activated sludge system was operated in a dramatically different fashion. Since control of MCRT had not produced desired results during 1976, it was decided to try and improve organic removal capability during the winter of 1977. As a result the MLVSS concentration was maintained 2.5 times greater during Period V than during Period II. The effect was better BOD_5 removal during Period V, averaging 92 percent versus 83 percent BOD_5 removal during Period II.

Periods III and VI were characterized by dramatic increases in hydraulic and organic loadings associated with the influx of tourists during the summer. A summary of the activated sludge loading and performance during these periods is presented in Table 17. As noted the first 4 weeks of Period III are

TABLE 17. SUMMARY OF ACTIVATED SLUDGE PERFORMANCE FOR OPERATIONAL PERIOD III AND PERIOD VI

Parameter	Period III 6/12/77 to 9/4/77	Period VI 5/14/78 to 7/30/78
Flow (mgd)	0.91	0.80
BOD_5		
Influent (mg/l)	397	310
Effluent (mg/l)	89	43
Removal (%)	78	86
TSS		
Influent (mg/l)	271	250
Effluent (mg/l)	123	20
Removal (%)	55	92

(continued)

TABLE 17. (Continued)

Parameter	Period III 6/12/77 to 9/4/77	Period VI 5/14/78 to 7/30/78
TKN		
Influent (mg/l)	44	---
Effluent (mg/l)	28	26
NH_4-N		
Influent (mg/l)	25	22
Effluent (mg/l)	24	17
NO_2&NO_3-N		
Influent (mg/l)	0.6	0.9
Effluent (mg/l)	2.0	4.5
Alkalinity (as $CaCO_3$)		
Influent (mg/l)	172	151
Effluent (mg/l)	144	116
pH (median)		
Influent (unit)	7.2	7.2
Effluent (unit)	7.0	6.8
MLSS (mg/l)	3125	4103
MLVSS (mg/l)	2270	3086
MCRT (days)	5	8
F/M (lb BOD_5/lb MLVSS)	0.67	0.31
Organic Load (lb BOD_5/day/1000 ft^2)	95	65.0
Clarifier OFR (gpd/ft^2)	724	636

mgd x 3785 = cu m/day; lb BOD_5/day/1000 ft^3 x 16 = gm/cu m; gpd/ft^2 x 0.0408 = cu m/day/sq m

omitted because the plant was involved in a scheduled shut- down during which time modifications were made to the gates separating the aeration basins. This shut-down required reseeding and start-up during Period III, which further hindered performance.

The BOD_5 load during Period III was 4.6 times greater than during Period II. Similarly, the BOD_5 load was 3.2 times greater during Period VI than during Period V. (Note: Period VI loading was lower because the Estes Park Sanitation District flow was stopped on June 1, 1978). These increased loadings occurred over a three-month period, and no changes in the activated sludge process configuration were made. (i.e., one-half of the activated sludge process units were in service). The rapid increase in loading resulted in reduced process efficiency. It should be noted that the loading itself and/or process operating parameters like organic loading, F/M, clarifier overflow rate, etc., were not significantly high in themselves. The main aspect that led to disrupted performance was the occurrence of the higher loading over a relatively short period of time and associated inability of the activated sludge system to quickly react. This aspect of a long time for biological system response has been further supported by other research.(2) To achieve satisfactory performance during the high summer loading period it is necessary that the UTSD plant staff allow sufficient time prior to the peak summer loadings to acclimate the activated sludge process to handle the peak loading conditions.

Insignificant ammonia oxidation occurred during Period III and Period VI. This was felt to be due to the relatively high organic loadings. At the same time a significant increase in ammonia load to the nitrification tower occurred.

NITRIFICATION

The wastewater directed over the nitrification tower consisted of flow received from the activated sludge process plus flow that was recirculated around the tower. The maximum pumping volume to the tower was 22,710 cu m/day (6 mgd), which provided a maximum recirculation capability of 4:1 at the plant design flow rate. The tower was divided into two equal volumes, each containing a different type of media. The east side of the tower contained plastic dumped media which had a specific surface area of 89 sq m/cu m (27 sq ft/cu ft). The west side contained redwood media which had a specific surface area of 46 sq m/cu m (14 sq ft/cu ft). In order to approach design loadings on the media, only one half of the tower was operated at any one time; a side by side comparison of the two types of media was not possible. During the project the plastic media was operated first and continued through September, 1977. The redwood media was then operated for the duration of the project.

Each media type was operated during three different phases called: start-up, cold weather and warm weather periods. The separation point between the cold weather and warm weather periods was arbitrarily selected as the point when the tower effluent wastewater temperature dropped below 8°C. Using this division point resulted in a split of approximately 5 months of cold weather operation and 7 months of warm weather operation during a one-year time frame. The start-up period for each media type occurred during a warm weather period. Therefore, during the two-year data collection phase of the research effort each media type was operated during a warm weather start-up period, a cold weather operating period and a warm weather operating period. These operating periods are labeled plastic start-up; plastic cold weather; plastic warm weather; redwood start-up; redwood cold weather and redwood warm weather operation.

After the data collection phase of the research project was completed, additional and important data was obtained relative to the performance of the nitrification tower. Operation using the redwood media was continued, and some warm-weather and some cold-weather results were documented. (Note: These results were obtained on 1 to 2-day per week composite samples as opposed to 5-day per week composite samples collected during the research project. Additionally, only a portion of the analyses conducted during the project were completed. This additional evaluation was separated into two operational periods called redwood update - warm weather and redwood update - cold weather.)

Table 18 presents the average data for the selected operational phases that were evaluated. An evaluation of this data is presented in the discussions of the various operational phases. It is important to note that the

TABLE 18. SUMMARY OF NITRIFICATION SYSTEM RESULTS

PARAMETER		Plastic Start-Up	Plastic Cold-Weather	Plastic Warm-Weather	Redwood Start-Up	Redwood Cold-Weather	Redwood Warm Weather	Redwood §§ Update Warm-Weather	Redwood §§ Update Cold-Weather
		**	†	††		§			
Inclusive Operating Dates	---	7-1/11-27-76	11-28-76/4-23-77	4-24/9-24-77	9-25/11-19-77	11-20-77/4-22-78	4-23/7-29-78	10-22-78/11-18-78	11-19-78/2-24-79
Data Evaluation Dates	---	8-22/11-27-76	12-26-76/4-23-77	"	"	12-25-77/4-22-78	"	"	"
No. of Weeks	---	14	17	20	8	17	14	4	14
Wastewater Flow (Q)	mgd	0.34	0.46	0.77	0.37	0.43	0.75	0.24	0.40
Recirculation Flow (R)	mgd	1.67	0.34	0.57	0.93	0.96	0.58	1.1	0.82
Recirculation Ratio (R/Q)	---	4.9	0.74	0.74	2.5	2.2	0.77	4.6	2.0
Tower Wetting Rate (min.)	gpm/ft^2	0.97	0.32	0.66	0.81	0.89	0.78	---	---
(avg.)	gpm/ft^2	1.28	0.57	0.95	0.96	0.98	0.94	0.95	0.86
(max.)	gpm/ft^2	1.38	0.93	1.18	1.06	1.16	1.15	---	---
Ammonia Loading	lb/day/ 1000 ft^3	0.4	2.0	7.3	0.4	3.7	7.0	1.6	2.7
BOD_5 Loading	1000 ft^3	7.6	7.2	16.4	8.7	3.5	16	3.2	4.1
Temperature (Inf)	°C	13	6	15	12	6	13	11	4
(Eff)	°C	13	5	15	12	5	13	10	3
NH_4-N (Inf)	mg/l	2.1	7.3	15.7	1.7	14.2	15.4	11.3	11.0
(Eff)	mg/l	0.8	5.1	8.1	1.4	10.6	9.1	0.7	3.1
(Oxidation)	%	62	30	48	18	25	41	94	72
TKN (Inf)	mg/l	6.5	9.7	19.0	5.9	16.8	18.4	---	---
(Eff)	mg/l	4.1	7.6	12.1	5.7	13.3	13.6	---	---
NO_2NO_3-N (Inf)	mg/l	13.2	2.0	3.5	15.4	1.4	3.7	---	---
(Eff)	mg/l	13.4	3.9	12.6	15.9	6.0	9.0	---	---
pH* (Inf)	unit	5.8	6.8	6.8	5.9	6.6	6.6	---	---
(Eff)	unit	6.4	7.2	6.9	6.8	7.3	7.1	---	---
Alkalinity (Inf)	mg/l	32	73	107	26	105	114	112	95
(Eff)	mg/l	28	58	51	21	74	65	29	37

mgd x 3785 = cu m/day; gpm/ft^2 x 40.7 = l/min/sq.ft;

*Median pH values are recorded.

**First 7 weeks excluded because of effects of Big Thompson Flood Disaster.

†First 4 weeks excluded because extensive nitrification occurred in activated sludge process.

††Excludes 2 weeks from 6-19-77 to 7-2-77, during which time the activated sludge basins were repaired.

§First 5 weeks excluded because extensive nitrification occurred in activated sludge process.

§§Limited data collected subsequent to research project data collection phase.

UTSD nitrification system was designed to meet an ammonia discharge limit of 54.8 kg/day (120 lb/day) which is the level that was projected to protect against ammonia toxicity in the Big Thompson River under 7 day, 10 year low flow conditions. This discharge limit would allow an effluent ammonia concentration of 10 mg/l at the design flow rate of 5678 cu m/day (1.5 mgd). This design requirement was met throughout the research project. However, the evaluation of nitrification capability presented in this report is based on the ability of the nitrification process to perform at more constraining levels of effluent ammonia concentration (i.e. > 2 mg/l NH_4-N) and/or at greater than 90 percent ammonia oxidation across the tower.

An overall summary of the nitrification results for the entire research project showing mass of ammonia applied to the tower and mass of ammonia converted to nitrate nitrogen by the tower is graphically illustrated in Figure 10. Also shown are the dates associated with the various operational periods. The bottom line in the graph depicts mass converted and not mass remaining in the tower effluent. As shown, the mass of ammonia applied was extremely variable throughout the project, ranging from less than 2.3 kg/day (5 lb/day) to more than 114 kg/day (250 lb/day). The low ammonia loadings were usually associated with periods where nitrification was occurring in the activated sludge process. The high ammonia loadings occurred during the summer tourist season.

The mass of ammonia oxidized also varied substantially throughout the research project. Many operational and environmental factors contributed to this variability. Low ammonia loading to the tower resulted because nitrification occurred in the activated sludge process; a rapid increase in ammonia loading occurred during the Christmas holiday season and extremely high ammonia loadings occurred during the summer tourist season. In addition, different operational procedures were implemented as the project progressed, the major change being in the amount and method of maintaining recirculation around the tower. Environmental factors such as wastewater pH, alkalinity and temperature also contributed to the variability of tower performance. These aspects are discussed for each of the operational phases evaluated.

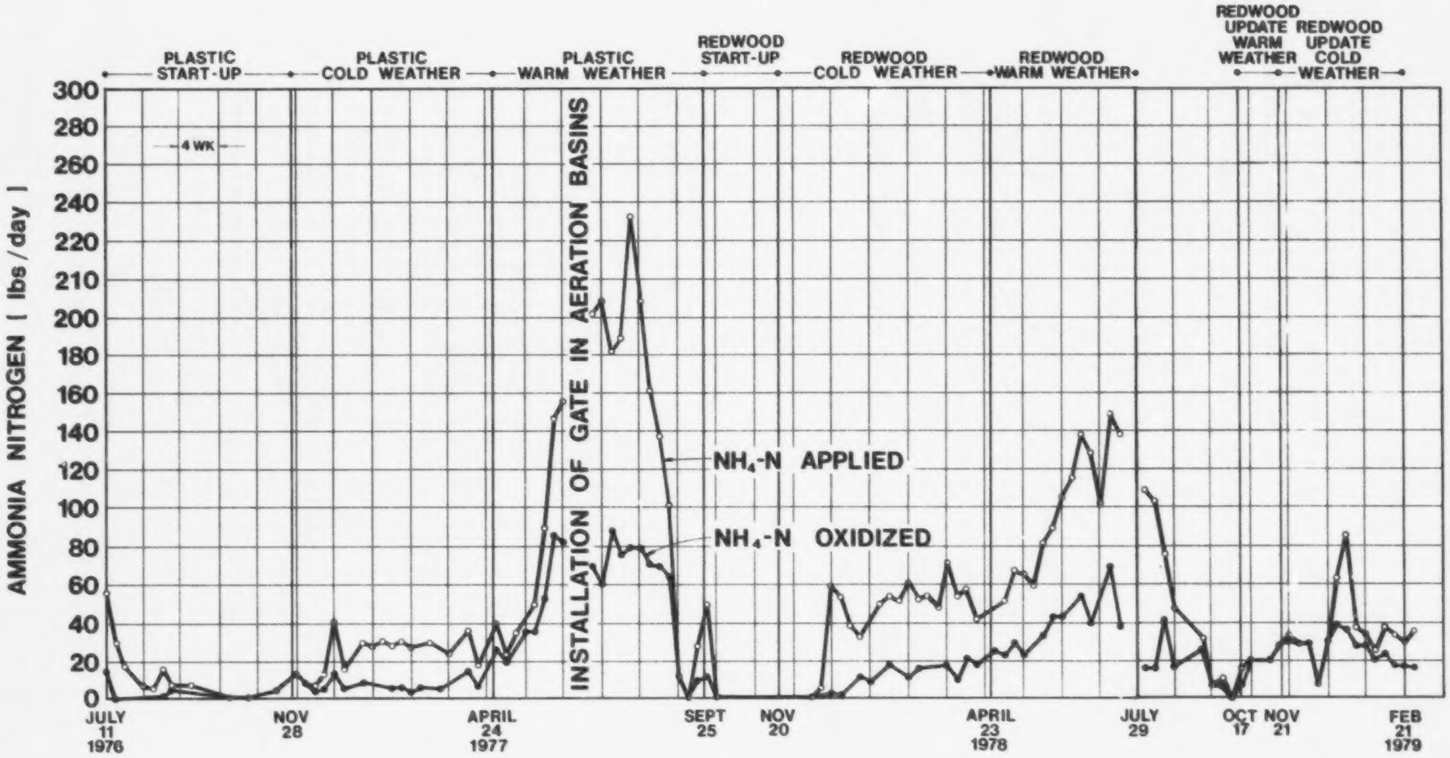


Figure 10. Nitrification tower ammonia loading and ammonia oxidized during the research project.

Plastic Start-Up (July 11, 1976 to November 27, 1976 - 20 wks)

Data collection for the nitrification tower plastic start-up period began on July 11, 1976, but was interrupted on July 31, 1976, when the Big Thompson flood disaster occurred. Because of this interruption the data presented in Table 18 for this period includes only those results after the effects of the flood were minimized (i.e., 8/22/76 to 11/27/76). The period ends on 11/27/76 when the tower effluent temperature dropped below 8°C. During the plastic start-up period the ammonia loading to the tower was minimal because nitrification occurred in the activated sludge process. The average ammonia loading to the tower was only 6.9 gm/day/cum (0.43 lb day/1000 ft^3), or 6 percent of the design loading of 109 gm/day/cum (6.8 lb day/1000 ft^3). This low loading limited the development of nitrifying organisms on the plastic media. The variations in ammonia loading and ammonia oxidation for the plastic start-up phase are graphically depicted in Figure 11.

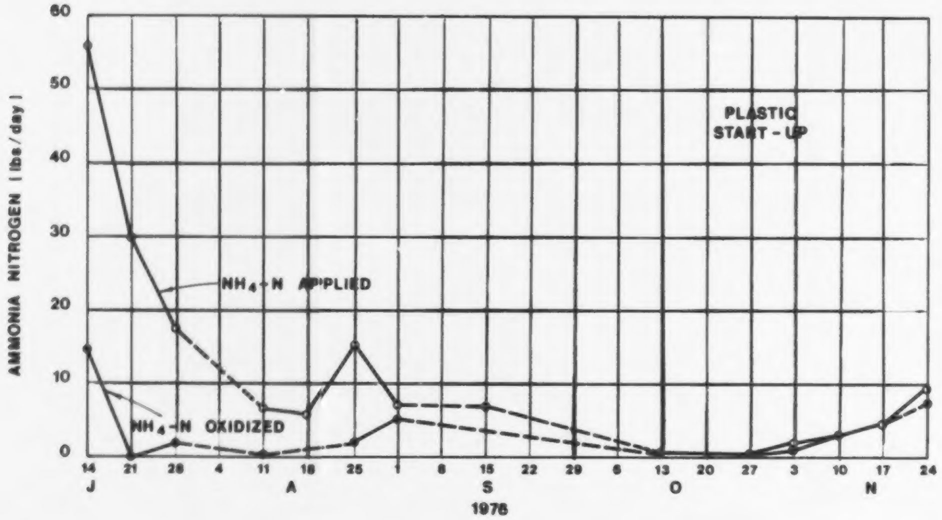


Figure 11. Nitrification tower ammonia loading and ammonia oxidized during the plastic start-up operating period.

The tower operational procedure during the plastic start-up period was to maintain a fairly high tower recirculation (R/Q) ratio (average was 4.9). The corresponding tower wetting rate averaged 52 l/min/sq m (1.28 gpm/ft^2) and varied from 39 to 56 l/min/sq m (0.97 to 1.38 gpm/ft^2). During the other operational periods the R/Q ratio and associated tower wetting rates were generally decreased. Initially, the tower wetting rate was quite variable, but finally was controlled at a more constant rate. The reasons for the changes in R/Q and tower wetting rate are presented in the operational phases where the changes occurred.

The R/Q ratio and wetting rate was maintained at higher levels during the plastic start-up period because the original tower distribution system could not evenly distribute a low flow rate over the media surface. At low flow rates it was felt that poor distribution resulted in loss of utilization of part of the dumped media in the upper portion of the tower. Therefore, the system's original fixed splash-plate nozzles were replaced with a variable flow splash-plate nozzle, which automatically adjusted themselves to provide good distribution at low flow rates. The new nozzles functioned very satisfactorily and provided an even distribution of flow over the media surface at low, as well as higher flow rates. A summary of the significant events that occurred during the plastic start-up period is presented in Table 19.

TABLE 19. SIGNIFICANT EVENTS DURING THE PLASTIC MEDIA START-UP PERIOD

Date	Event
July 11, 1976	Plastic dumped media section of tower placed into operation.
July 31, 1976	Big Thompson Flood Disaster occurred.
August 22, 1976	Data collection subsequent to the flood initiated.
October, 1976	Replaced fixed splash-plate nozzles with variable flow nozzles.

(Continued)

TABLE 19. (Continued)

Date	Event
August thru November, 1976	Tower influent ammonia concentration quite low due to nitrification in the activated sludge process.
August thru November, 1976	Tower recycle (R/Q) ratio and wetting rate were high at 4.9 and 52 l/min/sq m (1.28 gpm/sq ft), respectively.

Plastic - Cold Weather (November 28, 1976 to April 23, 1977 - 21 wks)

The plastic cold weather operating time period began when the tower effluent wastewater temperature dropped below 8°C. Initially, a low ammonia loading existed and lasted for about 4 weeks, as shown in Figure 12. Then, ammonia oxidation ceased in the activated sludge process and a higher ammonia loading was applied to the tower for the remaining 17 weeks of the plastic

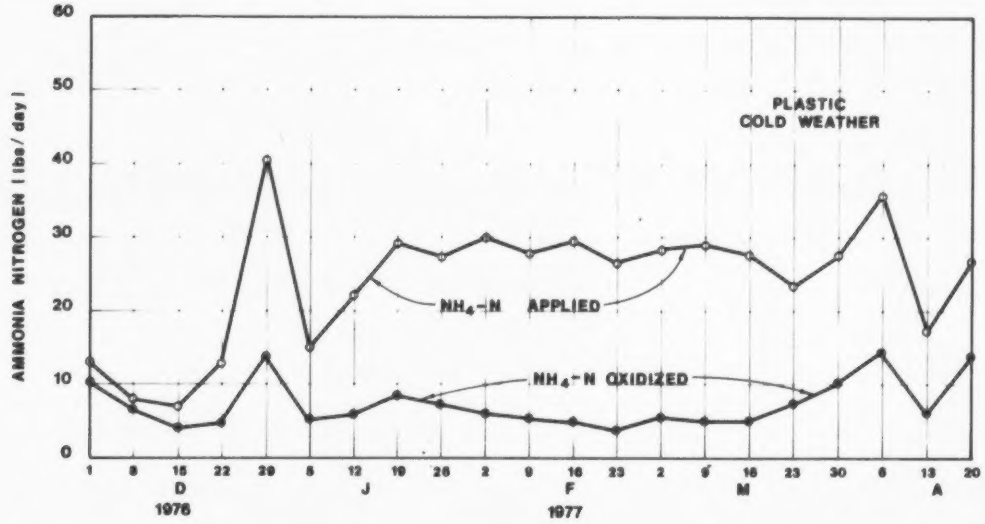


Figure 12. Nitrification tower ammonia loading and ammonia oxidized during the plastic cold weather operating period.

cold weather operating period. A summary of the results for the 17-week period of cold weather operation with a higher ammonia loading is shown in Table 18. The ammonia loading during this time period averaged 32 gm/day/cum (2.0 lb/day/1000 ft^3) or 465 percent greater than during the start-up period. However, this loading was still only about 30 percent of the design loading rate.

Initially the operational approach during the plastic cold weather period was to maintain a fairly high tower recycle ratio (R/Q) of about 2.8. However, ammonia oxidation began to gradually decrease from about 80 percent to 30 percent. It was felt that higher recycle rates were contributing to temperature losses in the tower, which in turn were contributing to the decreased tower performance. Therefore, the tower R/Q ratio was reduced gradually from a peak of 2.8 to 0. This gradual reduction occurred over an 8-week period, and no recirculation was provided for another 8-week period. When recirculation was reduced and eventually stopped, nitrification performance did not improve; in fact, ammonia removal further decreased to only about 20 percent. This gradual reduction in ammonia removal is illustrated in Figure 12; which depicts the mass of ammonia applied and mass oxidized during the plastic - cold weather period. Tower recirculation was stopped on 1/23/77, and was not started until the week of 3/13/77. During that time the amount of ammonia oxidized in the tower dropped from 3.6 kg/day (8 lb/day) to 2.3 kg/day (5 lb/day), while ammonia loading to the tower remained fairly constant at about 12.7 kg/day (28 lb/day). It was concluded that minimal recirculation did not improve nitrification performance.

During the week of March 13, 1977, recirculation was again implemented at an R/Q ratio of about 1.5. Subsequent to this change, ammonia oxidation increased from about 20 percent to 50 percent over a 5-week period, although the tower effluent temperature also gradually increased from 4°C to 8°C. It appeared that by providing some recirculation ammonia oxidation capability improved, but the benefits of recirculation alone could not be confirmed because wastewater temperature also increased. A summary of the events that occurred during the plastic - cold weather operating period is shown in Table 20.

TABLE 20. SIGNIFICANT EVENTS DURING THE PLASTIC - COLD WEATHER PERIOD

Date	Event
11/28/76 to 12/26/76 (4 weeks)	Low ammonia loading to tower due to nitrification in activated sludge process.
12/26/76 to 1/1/77 (1 week)	Ammonia oxidation in activated sludge process ceased.
11/28/76 to 1/22/77 (8 weeks)	Ammonia oxidation performance decreased from about 80 percent to 30 percent, over which time tower recirculation rate was gradually decreased from about 2.8 to 0.
1/23/77 to 3/19/77 (8 weeks)	No recirculation provided, and ammonia oxidation decreased from about 30 percent to 20 percent.
3/20/77 to 4/23/77	Recirculation provided at R/Q ratio of about 1.5; tower effluent temperatures gradually increased from about 4°C to 8°C; and ammonia oxidation gradually increased from about 20 percent to about 50 percent.

Plastic - Warm Weather (April 24, 1977 to September 24, 1977 - 22 weeks)

On April 24, 1977, the tower effluent temperature above 8°C and the plastic - warm weather operational period began. This operating period continued until the redwood media was placed on line on September 25, 1977. In total, this period continued for 22 weeks but was interrupted for 2 weeks in order to complete a scheduled repair to the activated sludge aeration basin gates. A summary of results during the plastic warm weather period is shown in Table 18.

The ammonia oxidation performance of the tower during the plastic - warm weather operational period is illustrated in Figure 13. As shown, the amount of ammonia loading and oxidation increased dramatically from 4/24/77 to 6/18/77. Two important points are depicted in Figure 13; the rapid increase in the amount of ammonia oxidized and the overall maximum amount of ammonia oxidized. The amount of ammonia oxidized increased from about 17 kg/day to 36 kg/day (37 lb/day to 80 lb/day) within a 4-week period, which relates to a 0.73 kg/day/day (1.6 lb/day/day) increase. This rate of increase in ammonia

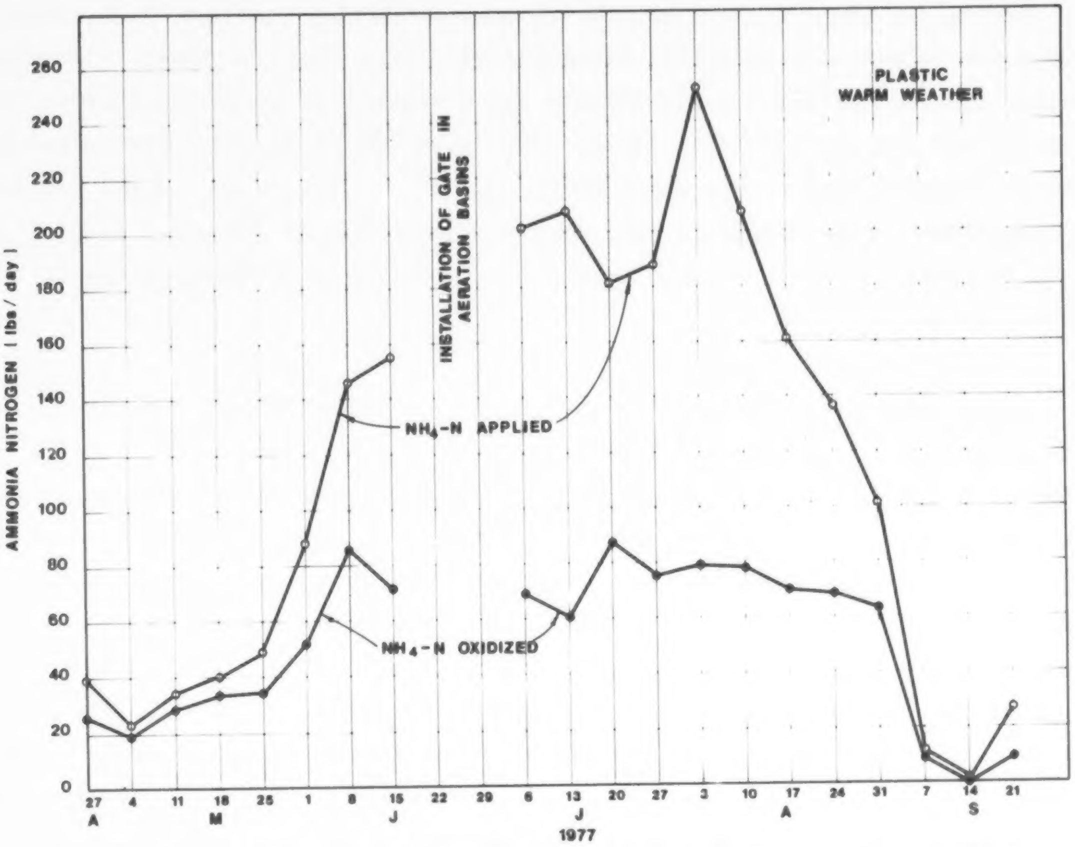


Figure 13. Nitrification tower ammonia loading and ammonia oxidized during the plastic warm weather operating period.

oxidation capability is compared to the response of the redwood media later in the report. A maximum ammonia oxidation capability of about 36 kg/day (80 lb/day) was achieved. A similar maximum ammonia oxidation also occurred later in this phase after a scheduled interruption occurred. Ammonia loading during this period was much greater than the maximum oxidation rate that was achieved. As such, relatively poor ammonia removal percentages were achieved (i.e. 48 percent). It is noted that an oxidation of 36 kg/day (80 lb/day) represents an oxidation per unit volume in the tower of 93 gm/day/cu m (5.8 lb /1000 ft^3/day). The corresponding oxidation per unit of media surface area in the tower was 1.03 gm/day/sq m (0.21 lb/day/1000 ft^2) of media surface. These values will be compared to the removal performance of the redwood media later in the report.

During the plastic warm weather operational period problems were encountered due to periodic extensive sloughing of solids from the tower. Sloughed solids plugged the mixed media filters which resultd in shut-down of both the filters and the nitrification tower. The tower had to be shut down since it was an integral part of the mixed media pressure filter system. These periodic shut-downs dramatically pointed out the limitations of the mixed media filters to handle periods of high solids loss from the nitrification system, as described later.

It was originally felt that a portion of the sloughing problem was due to the diversion of raw wastewater over the tower during the two week period in June 1977 when the gate structure between the activated sludge aeration basins was modified. This diversion was felt to have contributed to the development of a greater mass of carbonaceous organisms that sloughed off the tower when the raw wastewater flow to the tower ceased. However, sloughing was occurring prior to this time and continued after the gate modification for the remaining 11 weeks of the plastic warm weather evaluation period. Flow variations that occurred in tower wetting rates was felt to be another possible cause of the tower sloughing problem. However, no direct correlation between wetting rates and sloughing could be established from the data.

For the 4-week period from 7/17/77 to 8/13/77 while sloughing occurred periodically and while loading exceeded oxidation, the amount of ammonia oxidized varied from 34 to 39 kg/day (75 to 87 lb/day). This relatively small fluctuation could lead to the conclusion that the system had reached a consistent and maximum ammonia oxidation level. However, the tower sloughing and periodic shut-down (maximum 1-day duration at minimum 1-week intervals) may have hindered the nitrification system's ability to attain a higher level of ammonia oxidation. Despite the interference of tower sloughing, it was felt that the data indicated that the tower was capable of oxidizing a maximum fixed amount of ammonia. This conclusion is significant in that it requires that design loading be based on the maximum expected ammonia load that would occur for an average daily or weekly period, and not be based on yearly average loading conditions. A summary of the significant events that occurred during the plastic - warm weather operating period is shown in Table 21.

TABLE 21. SIGNIFICANT EVENTS DURING PLASTIC WARM WEATHER PERIOD

Date	Event
4/24/77 to 5/21/77 (4 weeks)	- Ammonia oxidation increased from 50 to 60 percent. - Mass of ammonia oxidized increased from 25.7 lb/day to 34.3 lb/day, while ammonia loading remained fairly constant at about 2.7 lb/1000 ft^3/day. - Tower recirculation ratio ranged from 1.0 to 1.6. - Tower wetting rate averaged 0.83 gpm/ft^2 and ranged from 0.76 to 0.92 gpm/ft^2.
5/22/77 to 6/18/77 (4 weeks)	- Tower ammonia loading increased four fold from 2.7 to 11.3 lb NH_3/1000 ft^3/day. (Note: 11.3 lb NH_3/1000 ft^3/day is 166% of design load). - Ammonia oxidation decreased from 86 to 46 percent, but mass of ammonia removed increased from 34 lb/day to 80 lb/day (i.e., rate of increase was 1.6 lb/day/day). - Extensive sloughing of solids from tower occurred, which required shut-down of mixed media filters due to plugging. - Tower effluent temperature increased from 10°C to 15°C. - Tower recirculation rate varied from 0 to 1.2 depending on flow rate.
6/19/77 to 7/2/77 (2 weeks)	Activated sludge aeration basin gates modified and all flow from the grit removal basin was diverted directly to the nitrification tower.
7/3/77 to 9/3/77	- Extremely high ammonia loading to tower occurred, ranging from 7.4 to 18.3 lb/1000 ft^3/day, or 109 percent to 269 percent of design. - After a 2-week period to overcome the effects of raw wastewater being directed over the tower, the maximum amount of ammonia oxidized was about 80 lb/day while loadings were almost 3 times that value. (Note: 80 lb/day relates to 5.8 lb/day/1000 ft^3 and 0.21 lb/day/1000 ft^2 media surface).

(continued)

TABLE 21. (Continued)

Date	Event
7/3/77 to 9/3/77 (Continued)	- Extensive sloughing of solids continued. Procedures were implemented to reduce the sloughing, including maintaining a nearly constant hydraulic load on the towers, and were met with only moderate success.
9/4/77 to 9/24/77	Ammonia oxidation in activated sludge process reoccurred.

lb/day x 0.454 = kg/day; lb/day/1000 ft^3 x 16.0 = gm/day/cum; gpm/ft^2 x 40.7 = l/day/sq m
lb/day/1000 ft^2 x 4.88 = gm/day/sq m

Redwood - Start-Up (September 25, 1977 to November 19, 1977 - 8 weeks)

On September 25, 1977 the redwood media was put into operation and the plastic media was removed from service. This change involved adjusting the proper valves to divert the influent to the other half of the tower. The redwood start-up period lasted for 8 weeks until 11/19/77, when the tower effluent temperature dropped below 8°C. During this time a negligible amount of ammonia was directed to the tower due to nearly complete nitrification that was occurring in the activated sludge process. The ammonia loading during the first week of start-up was 59 gm/day/cum (3.67 lb/day/1000 ft^3). But, the ammonia loading to the tower for the entire phase averaged 6.4 gm/day/cum (0.4 lb/day/1000 ft^3) because less than 1.6 gm/day/cum (0.1 lb/day/1000 ft^3) occurred for 7 weeks of the 8-week start-up period. These low loadings limited the development of a nitrifying population. A summary of the results during the redwood start-up period

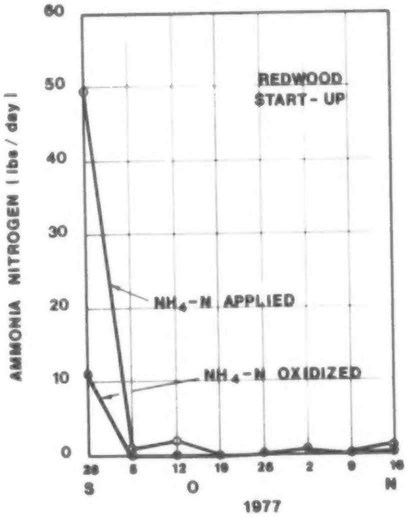


Figure 14. Nitrification tower ammonia loading and ammonia oxidized during the redwood start-up weather operating period.

is shown in Table 18, and a graphical illustration of NH_4-N load and NH_4-N oxidized is shown in Figure 14.

Redwood - Cold Weather (November 20, 1977 to April 22, 1978 - 22 weeks)

The cold weather period using the redwood media began on 11/20/77, when the tower effluent temperature dropped below 8°C. The lowest weekly average wastewater temperature during the 22-week time period was 3°C, and occurred for 2 separate one-week periods. During the first 5 weeks of the cold weather operational period, minimal tower ammonia loading existed because extensive nitrification occurred in the activated sludge process. High organic loading and low temperatures which occurred over the Christmas holidays caused nitrification in the activated sludge process to cease, and for the next 17 weeks the redwood tower was loaded at an average level of 59 gm/day/cum (3.7 lb/day/1000 ft^3) which was 54 percent of the design loading rate. The following discussion about redwood - cold weather operation includes data collected during the 17-week time period only. A summary of the results for the 17-week period is shown in Table 18.

The increase in tower ammonia loading began on 12/25/77, and continued throughout the remaining 17 weeks of the cold weather operational time period. A graphical illustration of the amount of ammonia applied to the tower and amount oxidized in the tower for the redwood cold weather period is shown in Figure 15. As shown, negligible ammonia oxidation occurred for the first 2 weeks. Subsequently, a gradual increase in ammonia oxidation occurred to a maximum level of 9.1 kg/day (20 lb/day), which was about 45% of the tower loading. The increase in ammonia removal to 20 lb/day occurred over a 15-week period, for an average increase of 0.077 kg/day/day (0.17 lb/day/day).

The maximum oxidation level of 9.1 kg/day (20 lb/day) was better than was obtained during the previous year when the plastic media was operated. Different operational procedures may have contributed to this occurrence. The most important operational change was in the tower recirculation ratio. The R/Q ratio during the plastic cold weather operation was always quite low, and

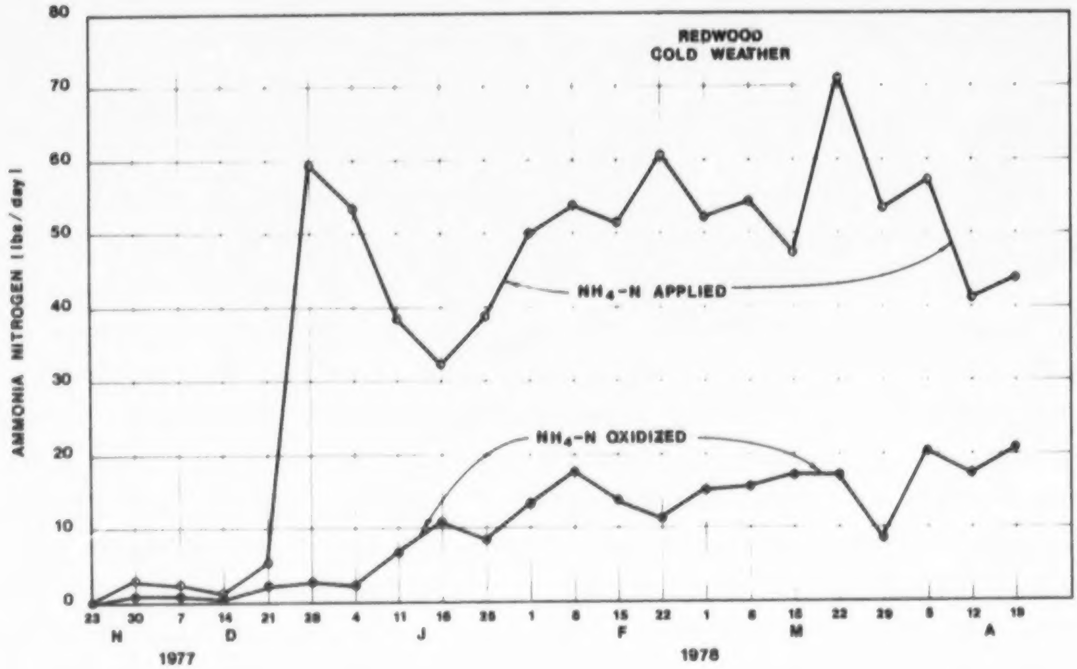


Figure 15. Nitrification tower ammonia loading and ammonia oxidized during the redwood cold weather operating period.

was eventually reduced to zero during most of the period. Conversely, the R/Q ratio during the redwood cold weather operation was substantially higher at 2.5. It appeared that a higher recirculation ratio improved ammonia oxidation performance during the cold weather operation. During the first winter (Plastic Cold Weather Period) it was felt that recirculation would possibly reduce the wastewater temperature and adversely affect ammonia oxidation capability. However, during the redwood cold weather period with recirculation, the temperature drop through the tower averaged 1°C. A similar temperature drop occurred during the plastic cold weather period when negligible recirculation was provided, thus a significant effect of high recirculation on wastewater temperature was not observed.

The better cold weather tower performance using the redwood media may be attributed to the type of media itself. Possibly, the rough surface texture of the redwood as compared to the plastic material enhanced growth attachment. However, because of the differences in the recirculation ratio during each period and because of the indication that a higher recirculation ratio improved ammonia oxidation capability, no definite conclusions can be drawn as to which media type performed better during cold weather operation. Also, no definite conclusion can be drawn about overall cold weather tower performance because a limited population of nitrifying organisms was established during start-up. Additional information regarding cold weather operation for the redwood media was collected after the data collection phase of the research project was concluded. In this case, good pre-cold weather start-up conditions existed. A summary of the significant events for the redwood cold weather period is shown in Table 22.

TABLE 22. SIGNIFICANT EVENTS DURING REDWOOD - COLD WEATHER PERIOD

Date	Event
11/20/77 to 12/24/77 (5 weeks)	Negligible ammonia loading to tower due to extensive nitrification in activated sludge process.
12/25/77 to 12/31/77 (1 week)	Nitrification in activated sludge process ceased.
12/25/77 to 4/22/78 (17 weeks)	- Tower ammonia loading averaged 3.7 lb/day/1000 ft^3 or 54 percent of design loading. - Ammonia oxidation increased from 4 to 47 percent. - Negligible ammonia oxidation occurred during first 2 weeks (i.e., about 2 lb/day). - Gradual increase in ammonia oxidation occurred over next 15 weeks to a maximum level of 20 lb/day (i.e., average 0.17 lb/day/day increase). - Tower recirculation ratio averaged 2.5 and tower wetting rate averaged 0.98 gpm/ft^2.

lb/day/1000 ft^3 x 16 = gm/day/cum; lb/day x 0.454 = kg/day; gpm/ft^2 x 40.7 = l/min/sq m

Redwood - Warm Weather (April 22, 1978 to July 29, 1978 - 14 weeks)

On April 23, 1977, the tower effluent wastewater temperature increased above 8°C, which marked the beginning of the redwood warm weather operating period. A summary of the results for the redwood warm weather operating period is shown in Table 18 and Table 23. The results shown in Table 23 are separated into two 7-week periods, one representing the time period when the loading was below the design level and the second when the load was above the design level.

A graphical illustration of the ammonia loading and ammonia oxidized in the redwood warm weather period is shown in Figure 16. As shown, ammonia oxidized through the tower gradually increased from about 10.4 to 19.5 kg/day (23 to 43 lb/day) from 4/23/78 to 6/10/78 (7 weeks), for an average rate of increase of 0.18 kg/day/day 0.08 kg/day/day (0.40 lb/day/day). This rate was 2.4 times greater than the rate of increase that occurred during the cold

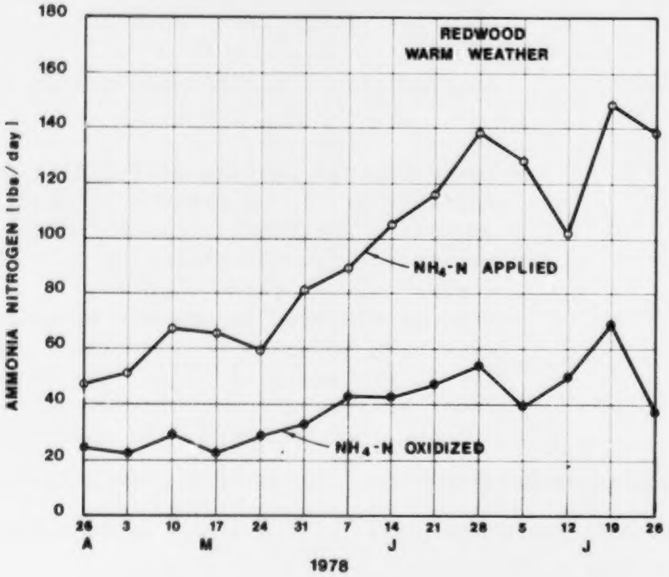


Figure 16. Nitrification tower ammonia loading and ammonia oxidized during the redwood warm weather operating period.

weather period (i.e., 0.81 versus 0.08 kg/day/day (0.41 versus 0.17 lb/day/day)), but was not as good as occurred for the plastic media. The plastic media increased its ammonia oxidation rate during a similar time period for the previous year an average 0.73 kg/day/day (1.6 lb/day/day). It appeared that the plastic media provided a more rapid response to increased ammonia loading during warm weather. Also, the maximum level of ammonia oxidized by the plastic media at about 36 kg/day (80 lb/day) was greater than the maximum level oxidized by the redwood media. The average mass of ammonia oxidized by the redwood media for the 7-week period from 6/11/78 to 7/29/78 was about 23 kg/day (50 lb/day). Thus, the plastic media responded more rapidly to a higher tower loading and performed at a greater ammonia oxidation level than the redwood media. A possible reason for this occurrence may be due to the increased surface area of the plastic media at 88 sq m/cum (27 ft^2/ft^3) as opposed to 46 sq m/cum (14 ft^2/ft^3) for the redwood media. These dry specific surface area values exclude the surface area attributed to growth on the media which would increase both values by an unknown amount. A comparison of the maximum unit oxidation rates for each media shows that the plastic material oxidized a maximum 1.03 gm/day/sq m (0.21 lb/day/1000 ft^2) of media surface and the redwood material removed a maximum 1.27 gm/day/sq m (0.26 lb/day/1000 ft^2) media surface. According to these values the redwood media oxidized about 20 percent more ammonia per unit of surface area, but overall the plastic media oxidized more ammonia because it had 52 percent more total media surface area.

The indication from the comparisons of media performance is that the plastic media had better overall ammonia oxidation capability than the redwood media. However, the plastic media was being loaded at a much higher level when its maximum ammonia oxidation occurred (i.e., at an average 218 gm/day/-cum (13.6 lb/1000 ft^3/day) versus 147 gm/day/cum (9.2 lb/day/1000 ft^3). This higher loading may have caused the plastic media to remove more ammonia. However, ammonia oxidation capability may not be the only factor that influenced media performance. During the redwood warm weather operational period minimal sloughing of solids occurred, unlike the problem with routine solids sloughing during the plastic warm weather operating period. During

TABLE 23. SUMMARY OF RESULTS DURING REDWOOD WARM WEATHER PERIOD (APRIL 23, 1978 TO JULY 29, 1978)

Parameter		4/23/78 to 6/10/78	6/11/78 to 7/29/78	4/23/78 to 7/29/78
Number of Weeks		7	7	14
Flow (Q) (mgd)		0.74	0.76	0.75
Recirculation Flow (R) (mgd)		0.62	0.53	0.58
Recirculation Ratio (R/Q)		0.84	0.70	0.77
Tower Wetting Rate (gpm/ft^2)	(min)	0.78	0.80	0.78
	(Avg)	0.96	0.91	0.94
	(max)	1.15	1.12	1.15
Ammonia Nitrogen Loading (lb/day/1000 ft^3)		4.8	9.2	7.0
BOD Loading (lb/day/1000 ft^3)		9.0	22	16
Temperature	Influent (°C)	10	15	13
	Effluent (°C)	10	15	13
Ammonia Nitrogen	Influent (mg/l)	11	20	15
	Effluent (mg/l)	5.9	12	9.1
	Removal (%)	45	39	41
Total Kjeldohl Nitrogen				
	Influent (mg/l)	14	23	18
	Effluent (mg/l)	8.0	19	14
Nitrite plus Nitrate Nitrogen				
	Influent (mg/l)	2.0	5.3	3.7
	Effluent (mg/l)	6.9	11.0	9.0
pH (median)	Influent (units)	6.6	6.7	6.6
	Effluent (units)	7.1	7.1	7.1
Alkalinity (as $CaCO_3$)	Influent (mg/l)	105	123	114
	Effluent (mg/l)	62	69	65

mgd x 3785 = cum/day; gpm/ft^2 x 40.7 = l/min/sq m; lb/day/1000 ft^2 x 16.0 = gm/day/cum each media type's warm weather operation condition, similar hydraulic wetting rates were experienced (i.e., redwood - 38 l/min/sq m average and 32 to 47 l/min/sq m variation (0.94 gpm/ft^2 average and 0.78 to 1.15 gpm/ft^2 variation) versus plastic - 39 l/min/sq m average and 27 to 48 l/min/sq m variation (0.95 gpm/ft^2 average and 0.66 to 1.18 gpm/ft^2 variation). The reason for sloughing from the plastic media and negligible sloughing from the redwood media was not known. The problem with the periodic solids sloughing by the plastic media was not that it significantly reduced ammonia oxidation performance, but rather that it plugged the mixed media filters and required system shut-down and bypass. This condition could have been avoided by using a different solids capturing unit, like a clarifier.

An important conclusion for both types of media was that an apparent maximum ammonia oxidation rate was achieved. The removal rates achieved possibly could have been improved by further optimizing operational adjustments, but the data indicates that some maximum oxidation level would be achieved. As such, nitrification towers should be sized on the anticipated peak daily or peak weekly ammonia loading, and not on an average yearly value. A summary of the events that occurred during the redwood warm weather operating period is shown in Table 24.

TABLE 24. SIGNIFICANT EVENTS DURING REDWOOD WARM WEATHER PERIOD

Date	Event
4/23/78 to 6/10/78 (7 weeks)	- Tower ammonia loading was gradually increasing, but was less than the design loading (i.e., varied from 3.4 to 6.5 lb/1000 ft^3/day or from 50 to 96 percent of design load). - Ammonia oxidation percentage remained constant at about 45%. - Ammonia oxidation level increased as ammonia loading increased and ranged from 20 lb/day to 43 lb/day. (Rate of increase was 0.47 lb/day/day). - Tower hydraulic loading averaged 0.97 gpm/ft^2 and varied from 0.78 to 1.12 gpm/ft^2.

(Continued)

TABLE 24. (Continued)

Date	Event
	- Minimal sloughing problems were encountered. - Tower recirculation ratio varied from 0 to 1.9 as flow rate varied. - Tower effluent temperature increased from 8°C to 12°C.
6/11/78 to 7/29/78 (7 weeks)	- Tower loading averaged 9.1 lb/1000 ft^3/day and varied from 7.7 to 10.8 lb/1000 ft^3/day, which was an average 134 percent above design load and varied from 113 to 159 percent above design loading. - Average ammonia oxidation rate was about 40%. - Maximum ammonia oxidation reached 69 lb/day for a one-week period, but was variable and averaged about 50 lb/day for the 7-week period. - Tower wetting rate averaged 0.92 gpm/ft^2 and varied from 0.80 to 1.12 gpm/ft^2. - Tower recirculation ratio averaged 0.71 and ranged from 0.54 to 1.08. - Minimal solids sloughing problems were encountered.

lb/day/1000 ft^3 x 16.0 = gm/day/cum; lb/day x 0.454 = kg/day; gpm/ft^2 x 40.7 = l/min/sq m

Redwood Update - Warm Weather (October 22, 1978 to November 18, 1978 - 4 weeks)

Subsequent to the data collection phase of the research project, limited but important information was developed regarding nitrification tower performance as shown in Figure 17. The most important fact was that the tower was loaded at a higher ammonia level prior to cold weather conditions than was achieved during the previous 2 years. The average tower loading was 26 gm/day/cum (1.6 lb/day/1000 ft^3), whereas loadings of only 1.6 and 6.4 gm/day/cum (0.1 and 0.4 lb/day/1000 ft^3) were achieved in 1977 and 1976, respectively. The loading of 26 gm/day/cum (1.6 lb/day/1000 ft^3) was about 24 percent of design. At that loading during warm weather operation the tower was achieving nearly complete ammonia oxidation. A complete summary of results for this time period is shown in Table 18. As shown, the average ammonia oxidation percentage was 94 percent. Therefore, unlike the previous two years the tower was receiving ammonia and was nitrifying prior to cold weather operation. The ammonia loading to the nitrification tower was increased by preventing nitrification in the activated sludge process. This was accomplished by substantially reducing and maintaining a low D.O. level. D.O. levels less than 0.5 mg/l were maintained in the aeration basin whereas levels of 2-4 mg/l were maintained during the previous two years. This operational change increased the ammonia loading to the tower, but more importantly allowed the tower to become acclimated for nitrification prior to cold weather operation.

Redwood Update - Cold Weather (November 20, 1978 to February 24, 1979 - 14 weeks)

On 11/20/78, the tower effluent temperature dropped below 8°C. As shown in Figure 17, from 11/20/78 until 12/24/78, ammonia oxidation rate was excellent. The oxidation rate varied from 90 to 95 percent. Between 9.1 and 13.6 kg/day (20 and 30 lb/day) of ammonia were removed and the tower loading was about 24 to 35 gm/day/cum (1.5 to 2.2 lb/day/1000 ft^3) or 22 to 32 percent of design. For two weeks from 12/26/78 and until 1/3/79, the ammonia loading more than doubled to 36 kg/day (80 lb/day) due to the Christmas tourist season. During that time the amount of ammonia oxidized increased from 13.6 to 18.2 kg/day (30 to 40 lb/day), but was only 50 percent of the influent loading. The tower was not able to quickly respond to the rapid increase in ammonia loading over the 8-day Christmas holiday period. It was concluded that the tower must be previously acclimated to these peak loading conditions in order to be able to oxidize the increased amount of ammonia at the expectd higher loading conditions.

After the Christmas holiday season the tower loading again dropped to about 13.6 to 18.2 kg/day (30 to 40 lb/day). At these loadings the tower ammonia oxidation was about 10.9 to 14.5 kg/day (24 to 32 lb/day), which represented an 80 percent removal. This level of ammonia oxidation was better than

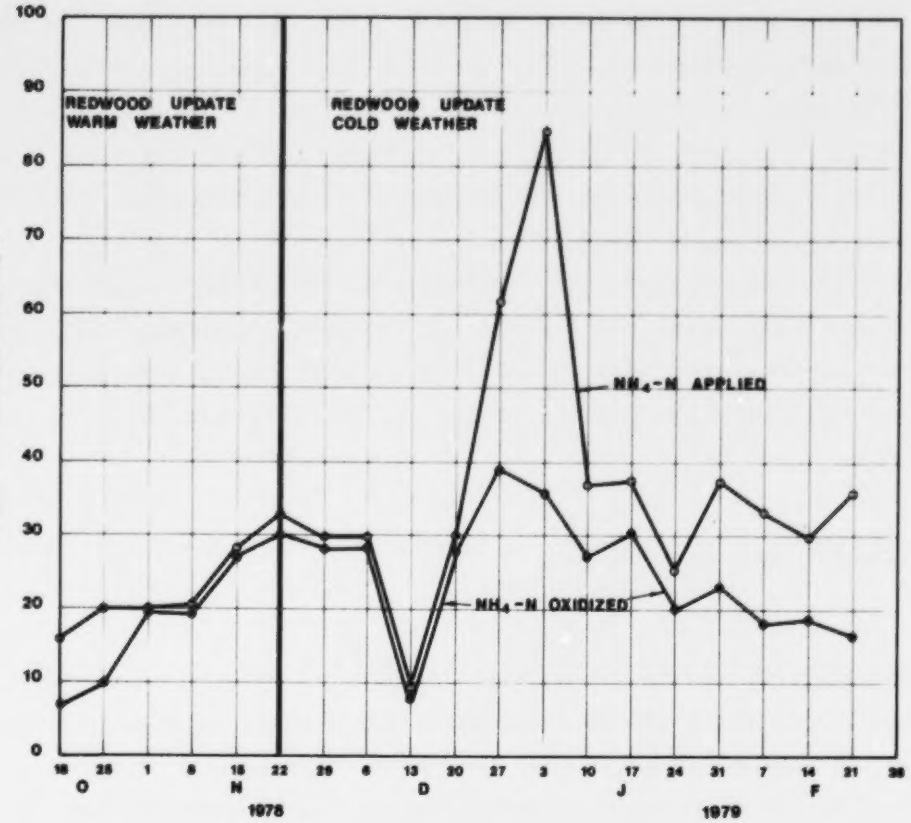


Figure 17. Nitrification tower ammonia loading and ammonia oxidized during the redwood update warm weather and redwood update cold weather operating periods.

the two previous cold weather seasons, but was reduced from the 90 percent that occurred prior to the Christmas holiday season. The 80 percent ammonia oxidation rate continued for 3 weeks from 1/7/79 to 1/27/79. Then, extremely cold weather occurred and the tower effluent temperature dropped to 1°C. Subsequently, tower ammonia oxidation gradually decreased from 80 percent to 50 percent, and only about 6.8 to 9.1 kg/day (15 to 20 lb/day of ammonia was oxidized. It is interesting to note that this level of ammonia removal was similar to that obtained during the redwood cold weather operational period of the previous winter. A summary of the results for the redwood cold weather period is shown in Table 18.

The updated information for cold weather tower operation indicated that initially, better ammonia oxidation existed when the tower was properly acclimated prior to the cold weather season. However, tower performance was affected by the cold weather and the tower oxidation rate decreased from 90 percent to 50 percent of the influent load. During this time, similar tower recirculation ratios and wetting rates existed at about 2.0 and 35 l/min/sq m (0.86 gpm/ft^2), respectively, as existed during the previous cold-weather period (i.e., 2.2 and 40 l/min/sq m (0.98 gpm/ft^2)). The tower effluent temperature ranged from 8°C to as low as 1°C to 2°C. These lower temperatures were 1°C to 2°C colder than previous winters due to a much colder than normal winter. It was concluded that even if the tower was acclimated, a significant cold weather effect does exist at the relatively cold wastewater temperatures experienced at the UTSD plant. A summary of the events that occurred during the redwood update cold weather period is shown in Table 25.

TABLE 25. SIGNIFICANT EVENTS DURING REDWOOD UPDATE - COLD WEATHER PERIOD

Date	Event
11/20/78 to 12/24/78 (5 weeks)	- Ammonia oxidation varied from 90 to 95 percent. - About 30 lb/day of ammonia was removed. - Tower loading was about 2.2 lb/day/1000 ft^3 or 32 percent design.
12/24/78 to 1/6/79 (2 weeks)	- Tower loading rapidly doubled to 80 lb/day (i.e., 5.8 lb/day/1000 ft^3 or 85 percent design).
1/7/79 to 1/27/79	- Tower loading decreased to 30 to 40 lb/day (i.e., 2.2. to 2.9 lb/day/1000 ft^3, or 32 to 43 percent of design). - Ammonia oxidation was about 80 percent.
1/28/79 to 2/24/79 (4 weeks)	- Tower loading remained at 30 to 40 lb/day. - Tower effluent temperature varied from 1°C to 3°C (colder than previous two winters). - Ammonia oxidation decreased from 80 to 50 percent.

lb/day x 0.454 = kg/day; lb/day/1000 ft^3 x 16.0 = gm/day/cum

Overall Nitrification Evaluation

Nitrification tower performance as compared to a > 90 percent oxidation capability was marginal throughout the research project, except during the fall and early winter of 1978, when 90 to 95 percent ammonia oxidation existed and the tower loading was about 32 percent of its design value. Several events occurred during various times of the research project that contributed to the tower's low overall ammonia oxidation efficiency. Among these were: negligible tower loading during start-up, rapid increases in tower loading during cold weather operation, summer loadings on one half of the tower that were significantly greater than design, periodic sloughing of solids from the tower which necessitated periods of shutdown, varying tower recirculation ratios, and low wastewater temperatures during cold weather operating periods. In addition to these items several other factors were felt to be potentially detrimental to ammonia oxidation capability of the tower; low pH and alkalinity. Controlled bench studies were conducted to test the potential impact of these items on the ammonia oxidation capacity of the UTSD plant.

The results of the bench test special studies showed that given sufficient time, complete nitrification always occurred. When alkalinity was added and the pH was increased, the rate of ammonia oxidation increased substantially and complete nitrification eventually occurred in all batch tests. It should be noted that the optimum pH for nitrification is above neutral (approximately pH 8.6). The pH of the tower influent was always on the acid side of neutral, and ranged from pH 5.8 to pH 6.8.

From these bench scale studies it was concluded that the full scale nitrification results during the research project could have been dramatically influenced by low wastewater pH. It was hypothesized that the lower overall pH values hindered the rate of ammonia oxidation capability through the towers, and sufficient time and/or exposure to the nitrifying microorganisms was not available to achieve good nitrification at the loading rates experienced. This hypothesis could not be confirmed during the research project.

Under present loading conditions it may be necessary to place the entire tower (both the redwood and plastic media) into service to achieve better ammonia oxidation capability. In so doing increased contact time with nitrifying microorganisms would be attained which would overcome the documented nitrification rate reducing effect of the low wastewater temperature and the hypothesized nitrification rate reducing effect of the relatively low wastewater pH. Also, increased ammonia oxidation capability would be provided for the peak ammonia loading time of the year (i.e., summer, tourist season). Better and possibly near complete nitrification may occur under existing loading conditions using all of the tower, except when shock loading conditions occur. To adequately handle the shock loads, tower acclimation using chemical ammonia addition may be required. Then, as plant flow rates and tower ammonia loadings increase, pH adjustment may be necessary to increase the rate of ammonia oxidation to consistent conversions of greater than 90 percent. It is noted that the existing nitrification facilities are not required to perform at high levels (i.e. > 90 percent ammonia oxidation efficiencies to meet the original projected design requirements.

DENITRIFICATION

The UTSD plant was designed to oxidize ammonia through the nitrification tower. Solids that were generated and sloughed from the tower were to be removed in the mixed media filters. This combination of unit processes was thought to have a potential for nitrogen removal by denitrification within the mixed media filters. If this was feasible, less expense would be encountered because the filter could serve a dual purpose as a polishing filter and as a support media for the denitrifying micro-organisms. The evaluation of the suitability of the mixed media filters for full scale denitrification was completed during two time periods. Period A lasted for 34 days (4/3/78 to 5/9/78) and Period B for 24 days (5/21/78 to 6/14/78). Twelve days time separated the two periods. The two time periods were differentiated by the number of filters on line and by a slightly different wastewater temperature. During Period A, one filter was on line and the average wastewater temperature was 9.4°C. During Period B, two filters were operated and the average wastewater temperature was 13.1°C. Two filters were placed into operation during Period B because of an increase in the plant flow rate, and because the filter used in Period A had a tendency to plug when methanol was added.

Filter influent and effluent flow proportioned samples were collected every two hours for a 24-hour period from Sunday through Thursday. Analyses conducted on most of the composited samples include NO_2/NO_3-N, NH_3-N, TKN, ALK, COD, BOD_5, and TSS. Temperature, D.O. and pH tests were conducted on grab samples. The performance of the filter with respect to run time and backwash requirements was also of special interest. Therefore, filtration rate, run time, head loss, backwash rate and backwash duration information was collected prior to, during, and after the denitrification study.

Start-Up Interval

Methanol was added to the filter influent to encourage the denitrification process. The methanol storage and feed system to provide this capability was designed and installed as part of the research project. Methanol was added to the filter influent at a point preceeding the existing in-line mixer. The amount of methanol added to accomplish denitrification was carefully controlled, since it was assumed that excessive methanol addition would lead to "break-through" and an increased BOD_5 and COD concentration in the filter effluent. The theoretical formula for determining the amount of methanol required has been developed by McCarty, et. al. as follows (3):

$$Cm = (2.47)\ (NO_3\text{-}N) + 1.53\ (NO_2\text{-}N) + 0.87\ (D.O)$$

where: Cm = mg/l of methanol required.
NO_3-N = mg/l of nitrate nitrogen in influent.
NO_2-N = mg/l of nitrite nitrogen in influent.
D.O. = mg/l of dissolved oxygen in influent.

Assuming that typical (4) influent concentrations to a denitrification process would be 25 mg/l nitrate, 0.5 mg/l nitrite, and 3 mg/l D.O., the theoretical amount of methanol indicated by this equation to achieve complete nitrogen removal would be 2.5 times the amount of nitrate in the feed system. Using the above assumed concentrations, the methanol requirement to satisfy the D.O. demand would be 4 percent of the total feed requirement. The percentage of methanol to satisfy the D.O. demand for the UTSD system was much greater than 4 percent. This increased demand of methanol to satisfy the D.O. requirement greatly influenced the start-up procedures.

The combined average of the results for both Period A and Period B are shown in Table 26. Also shown is information collected prior to the denitrification study. The start-up interval was separated into two time frames. One was labeled "Methanol Less than D.O. Requirements" (i.e. less than 0.87 x D.O. concentration) and the other "Methanol Greater than D.O. Requirements". As shown in Table 26, NO_2/NO_3-N removal prior to the denitrification study did not exist, in fact an increase occurred in the NO_2/NO_3-N concentration of the filter effluent. Correspondingly, there was an expected reduction in the NH_4-N and alkalinity concentrations of the filter effluent. Apparently, sufficient D.O. existed in the filter influent to allow nitrification to occur within the filter.

During start-up of the denitrification study, methanol was initially added in small quantities which were gradually increased. It was felt that excessive methanol additions would lead to breakthrough and an increase in the BOD_5 concentration of the final effluent. Therefore, during the initial start-up period the amount of methanol that was added was not sufficient to reduce the D.O. concentration to a point where denitrification would become predominant. An average 9.6 Kg/day (21.1 lb/day) of methanol was added whereas the methanol requirement to satisfy the D.O. requirement was 16.8 kg/day (37.1 lb/day) (i.e., 0.87 x mass of D.O. in filter influent). The result was that sufficient D.O. still existed to allow nitrification to dominate the reaction within the filter, and the effluent NO_2/NO_3-N concentration at 6.5 mg/l was greater than the influent concentration at 5.5 mg/l. However, at the same time, the effluent BOD_5 concentration increased by about 100 percent to 16 mg/l, indicating that some methanol breakthrough occurred. It

TABLE 26. SUMMARY OF DATA COLLECTED DURING PERIOD A AND PERIOD B OF THE DENITRIFICATION SPECIAL STUDY

		Start-Up (Acclimation)		
Parameter	Prior To Evaluation Periods	Methanol Less Than D.O. Required	Methanol Greater Than D.O. Required	Methanol Full Feed Interval
Number of Days (Combined Periods)	35	11	14	34
Wastewater Flow (mgd)	0.46	0.69	0.72	0.60
Methanol Added (lb/day)	0	21.1	72.1	111
M/N Ratio (lb/lb)	0	0.67	1.97	2.64
Methanol Demand for Oxygen Req'd (lb/day)*	25.1	37.1	35.5	27.8
D.O. Inf (mg/l)	7.5	7.4	6.8	6.4
NO_2NO_3-N Inf (mg/l)	5.3	5.5	6.1	8.4
Eff (mg/l)	6.5	6.5	5.3	3.8
Removal (%)	-23	-18	13	55
Filter Head Loss Rate H/L (ft/hr)	0.26	0.50	0.61	0.85
Filter Rate (gpm/ft^2)	2.22	3.03	2.31	2.26
BOD_5 Inf (mg/l)	24	27	36	30
Eff (mg/l)	8.1	16	17	19
Removal (%)	66	41	53	37
TSS Inf (mg/l)	12	11	18	19
Eff (mg/l)	4	2	3	4
Removal (%)	64	75	83	78
COD Inf (mg/l)	45	43	47	49
Eff (mg/l)	34	34	39	40
Removal (%)	24	21	17	18
TKN-N Inf (mg/l)	13.7	8.3	9.5	8.3
Eff (mg/l)	11.4	6.7	7.8	6.4
Removal (%)	17	19	18	23
NH_4-N Inf (mg/l)	10.6	6.5	7.2	6.3
Eff (mg/l)	9.2	5.6	6.3	5.7
Removal (%)	13	14	13	10
Alkalinity Inf (mg/l)	74	64	68	57
Eff (mg/l)	63	57	72	64
Removal (%)	12	11	-6	-12
Organic Nitrogen Inf (mg/l)	3.1	1.8	2.3	2.0
Eff (mg/l)	2.2	1.1	1.5	0.7
Removal (%)	29	39	35	65

mgd x 3785 = cum/day; lb/day x .454 = kg/day; gpm/ft^2 x 40.7 = l/min/ sq m
*Calculated assuming 0.87 lb methanol per 1.0 lb D. O.

should be noted that the methanol concentration in the filter effluent was not measured, thus it was not known if the increased BOD_5 concentration was due to methanol or due to a byproduct of the reaction. The term methanol breakthrough was used to describe increased organics in the efluent whch contributed to a higher BOD_5 concentration.

Despite the methanol breakthrough it was decided to add methanol at a rate that exceeded the D.O. requirement. When this was done, denitrification began to dominate the reaction and the study was considered to change from a pre-start-up to a start-up condition. Period A had pre-start-up interval of 9 days and Period B only 2 days. For each start-up interval, 7-days time was required before the denitrification rate reached its full potential. The conclusion was that the true start-up condition was reached only after the methanol feed rate exceeded the D.O. requirement, and was not heavily influenced by the pre-start-up time period when the methanol feed rate was less than the D.O. requirement.

An average NO_2/NO_3-N removal of 13 percent occurred during the start-up period when the methanol feed rate was greater than the D.O. requirement. Correspondingly, the filter effluent BOD_5 concentration was greater at 17 mg/l than during the period prior to the study at 8.1 mg/l. However, conclusive evidence of methanol breakthrough did not exist because the influent BOD_5 concentration during start-up at 36 mg/l was also greater than prior to the study at 24 mg/l. But, a trend for a slight increase in effluent BOD_5 due to methanol breakthrough is evident.

The influent TSS concentration was also slightly greater during start-up at 18 mg/l than prior to the study at 12 mg/l, but the effluent TSS concentration was better during start-up at 3.0 mg/l than prior to the study at 4.3 mg/l. Better TSS removal occurred indicating that biological growth within the media enhanced the filtering action. However, this biological growth also reduced the filter run time and increased the filter head loss rate which eventually caused the study to be halted.

Methanol Full-Feed Interval

Methanol was initially added to the filters in small amounts to encourage the growth of the denitrifying microorganisms and to minimize breakthrough. The dosage was then gradually increased as denitrification proceeded. This period of evaluation was called the methanol full-feed interval. The full-feed operating interval of Period A was 19 days and for Period B 15 days (total of 34 days). During each of these full feed operating intervals the amount of methanol added varied which provided different methanol to nitrate (M/N) feed ratios. The ratios encountered includes the requirements for nitrite and oxygen. Typically, methanol requirements for these parameters are small relative to the nitrate requirement (4). In this report the M/N ratios presented were calculated using mg of methanol fed per mg of NO_2/NO_3-N in the influent as a basis. It is noted, however, that the methanol requirement to satisfy the oxygen demand was higher than typical. Actual M/N ratios to achieve complete denitrification reportedly have ranged from 2.5 to 3.5 (4). Similar ratios were tested during the UTSD denitrification study. The percentage removal of NO_2/NO_3-N compared to the corresponding M/N feed ratio is shown in Figure 18. Data to make this analysis was available for twenty-one of the thirty-four full feed days.

The average NO_2/NO_3-N removal during methanol full-feed was 55 percent, and ranged from 29 percent to 99 percent. This range of removal appeared to be directly related to variable M/N ratios as shown in Figure 18. A linear relationship was developed between the NO_2/NO_3-N removal percentage and the M/N feed ratio. The number of data points for this analysis was limited due to the relatively short duration of each of the study periods caused by filter plugging problems. As shown in Figure 18, a M/N feed ratio of about 4.4 is indicated to achieve 90 percent removal of NO_2/NO_3-N, which is higher than the reported values mentioned earlier. Several reasons may have contributed to the higher M/N ratio, including relatively low operating temperature, too short a reactor detention time, and a relatively high influent D.O. concentration.

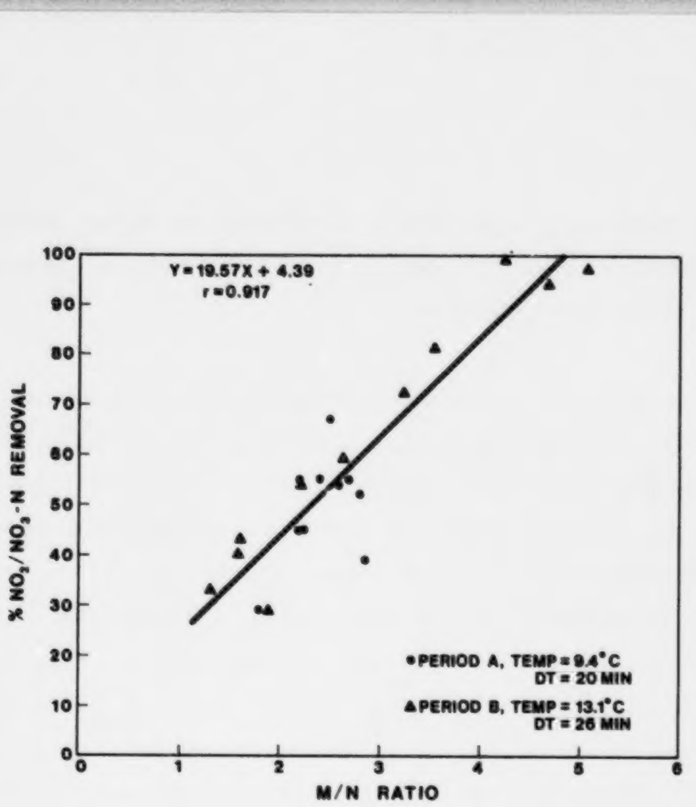


Figure 18. Percent NO_2/NO_3-N removal versus methanol to nitrate feed ratio for Period A and Period B denitrification study.

The average wastewater temperature for Period A was 9.4° C and for Period B 13.1° C. A slight trend for higher removal at a given M/N ratio when the wastewater is of a higher temperature is qualitatively illustrated in Figure 18. More of the data points for NO_2/NO_3-N removal for the higher temperature Period B are above the line of best fit. However, significant and conclusive data does not exist with these data points.

The reactor detention time varied from Period A to Period B, because one filter was used during Period A and two filters were used during Period B. The average wastewater flow rate during Period A was 1820 cum/day (0.48 mgd) and during Period B, 2840 cum/day (0.75 mgd). The corresponding reactor detention times with the appropriate number of filters on line was 20 min for Period A and 26 min for Period B. Reactor detention time was determined by using the entire volume of the mixed media pressure vessels. Media only occuppied approximately one half of the reactor volume, and therefore only about one half the detention time calculated was under packed bed conditions.

These detention times were apparently sufficient to allow denitrification to proceed, but may have been too short to allow complete denitrification in accordance with available methanol.

During the periods of study the average influent D.O. concentration was relatively high at 6.4 mg/l and the NO_2/NO_3-N concentration relatively low at 8.4 mg/l. The calculated M/N ratio includes the oxygen requirement because it is typically small (4 percent) relative to the nitrate requirements (4). For the full methanol feed period shown in Table 26 the average oxygen requirement was 25 percent of the M/N ratio. If the M/N ratio of 4.4 to achieve 90 percent NO_2/NO_3-N removal, as indicted in Figure 18, was adjusted for the oxygen requirement, then the M/N ratio would be 3.3 and move in line with reported values. The large amount of methanol required to satisfy the oxygen requirement at the UTSD was felt to be the major contributing factor to the higher than expected M/N ratios per unit NO_2/NO_3-N removal shown in Figure 18.

During full methanol feed some methanol breakthrough apparently existed because both the BOD_5 and COD concentration of the filter effluent were greater than prior to the study and their respective removal efficiencies were lower. The effluent BOD_5 concentration increased from 8.1 mg/l to 19 mg/l, and the BOD_5 removal efficiency decreased from 66 to 37 percent. The effluent COD concentration increased from 34 mg/l to 40 mg/l, and the COD removal efficiency decreased from 24 to 18 percent. It should also be noted that most of this data was collected when the NO_2/NO_3-N removal was less than 90 percent, and methanol addition was apparently less than the NO_2/NO_3-N requirement.

The only other major chemical change in the filter effluent that was measured during the denitrification study was in the alkalinity. During methanol addition the alkalinity of the filter effluent was greater than the filter influent. The TKN removal was slightly higher and NH_3-N removal was slightly lower. The overall results of the denitrification study to this point indicates that methanol addition to the mixed media filters does allow denitrification to proceed, and 90 percent NO_2/NO_3-N removal can occur if sufficient methanol is added to achieve the necessary M/N ratio. Some methanol breakthrough occurs, but does not increase the BOD_5 concentration to unacceptably high values. However, as shown in Table 26, the filter's rate of headloss (H/L) increased significantly when methanol was added. This increase in the rate of headloss eventually caused the study to be halted and will be further discussed.

Filter Performance (Physical Parameters)

The increase in the filter headloss rate could be attributed to an increase in solids production from denitrification and/or to the type of solids that were generated. The theoretical formula for solids production is as follows:

$$Cb = 0.53\ NO_3\text{-}N + 0.32\ NO_2\text{-}N + 0.19\ D.O.$$

where Cb = biomass production - mg/l
NO_3-N = Nitrate concentrations influent - mg/l
NO_2-N = Nitrate concentrations influent - mg/l
D.O. = D.O. concentrations influent - mg/l

Using the full-feed average NO_2/NO_3-N and D.O. concentrations at 8.4 mg/l and 6.4 mg/l, respectively, the theoretical biomass production was calculated at 5.7 mg/l. This value was 30 percent of the average influent TSS concentration of 19 mg/l. This increase in the solids removal requirement may have caused the filter headloss rate to increase somewhat, but not to the extent that occurred.

The rate of filter headloss was obtained by dividing the change in the filter loss of head between backwashes (H in Hg or ft of H_2O) by the length of time between backwashes (L in hours). Typically, the change in filter loss of head between backwashes was about 3.7 m (12 ft). The parameter that changed the H/L ratio was the length of time between backwashes. A low H/L ratio was desirable because it indicated that there were a minimum number of filter backwashes required.

The daily average H/L ratios for both Period A and Period B are shown in Figure 19. The H/L ratio during the methanol full-feed interval is shown. The average filtration rate during these periods was 92.0 l/min/sq m (2.26 gpm/ft^2).

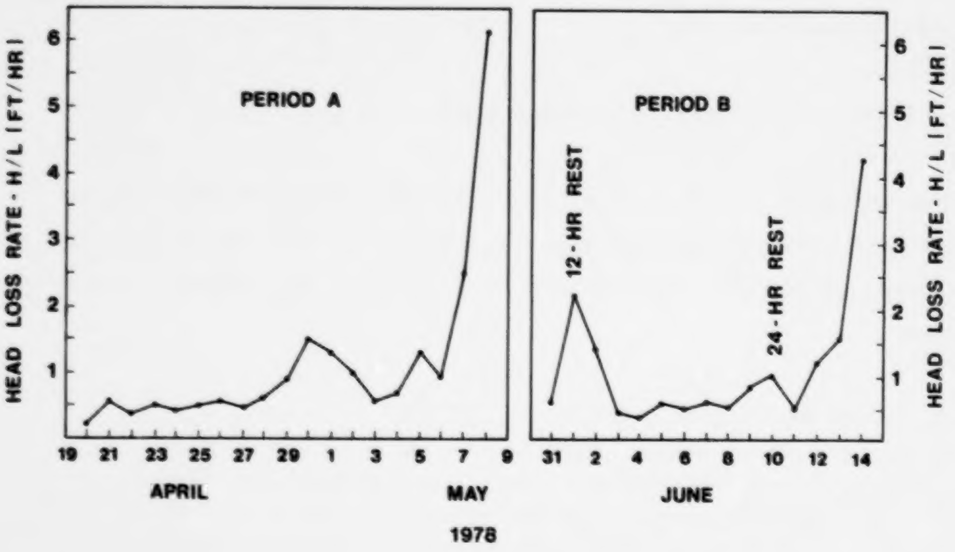


Figure 19. Filter head loss rate during Period A and Period B methanol full-feed operating interval. (ft/hr x 0.305 = m/hr).

As shown for Period A, the H/L ratio increased during the end of April and then decreased again. The reason for this increase was attributed to an increased wastewater flow rate. In Period B, the H/L ratio increased on 6/1/78 and again on 6/10/78, and decreased on subsequent days. In both of these cases the filters were taken off line for a period of up to 24 hours, which enabled them to recover somewhat. However, as shown, the H/L ratio increased significantly on the last operating day of both periods. Filter run times were reduced from about 24 hours to only 2 to 3 hours in both periods, and the system had to be shut down in both cases. This substantial reduction in filtration capability was the single most detrimental aspect concerning denitrification using the mixed media filters.

It was concluded from these results that substantially lower surface loading rates would be required if denitrification using a mixed media filter is to be feasible. However, several significant aspects concerning the UTSD study temper this conclusion. The filter influent D.O. concentration was higher than typically expected and probably contributed to excess biological growth on the filter media. The type of biological growth and/or the amount of growth associated with these higher D.O. values may have enhanced the filter plugging problem. Full documentation as to the validity of co-currently utilizing mixed media filters for filtration and denitrification cannot be made based on these results. What can be concluded is that the dramatic impact of filter plugging on this dual usage of mixed media filters certainly makes the denitrification aspect certain and worthy of special attention during similar future studies. Furthermore, a full-scale system design should not be completed without further study.

The filter backwash rate and duration during the dentrification study was maintained at 509 l/min/sq m (12.5 gpm/ft^2) and 15 min, respectively. Because of the relatively short periods of study, no attempt was made to change the backwash rate or duration during each evaluation period. After the evaluation had been completed, the backwash rate and duration were changed to determine any effects associated with the type of backwashing. In total, three different types of backwashing were investigated. The first type was a continuation of the backwash rate of 12.5 gpm/ft^2 and duration of 15 min. This was implemented after Period A on the one filter that was used for denitrification during that period. The H/L ratio initially was about 6.0, and the backwashing frequency had been reduced to two hour intervals. After 6 days and 12 backwashes, the H/L ratio decreaed to 0.5 and the backwashing frequency had increased to 24 hours intervals.

After the Period B evaluation, two different types of backwashing were implemented, one on each of the two filters that were used for denitrification during that period. On one filter a program of backwashing at a lower rate for a longer period of time was implemented. A rate of 8.7 gpm/ft^2 for 23 min. was used to try to achieve longer scrubbing action within the media. The H/L ratio initially was about 4.5 and the backwash frequency was about every 2 1/2 hours. After seven days and 14 backwashes, the H/L ratio decreased to 0.5 and frequency of backwashing had increased to 24 hour intervals. On the other filter that was used for denitrification during Period B, a rate of 13.2 gpm/ft^2 for 15 min. was used to achieve a more violent backwashing action. In this case the H/L ratio was again 4.5 and the backwash frequency was about every 2 1/2 hours. After only 4 days and 8 backwashes, the H/L ratio was reduced to 0.5 and the frequency of backwashing had increased to 24 hour intervals. The higher backwashing rate improved the recovery rate of the filter and represented a better backwashing program.

MIXED-MEDIA FILTRATION

Effluent from the nitrification tower was directed to the mixed-media filters where suspended material was captured and removed. The filtration system consisted of four pressure vessels, each containing a mixture of three different types of media and a gravel support system. The flow rate through the filters was matched to the nitrification tower flow rate by the use of a bubbler-tube system and rate-of-flow controllers. Filter backwashing was accomplished manually, but could also be initiated automatically. Ozonated plant effluent served as the backwash water supply. Backwash wastewater flowed to a separate storage basin and was eventually discharged at a controlled rate to the Thompson River Lift Station.

Data on filter performance was collected for the period of October, 1976 through April, 1978. Beginning in April, 1978, a study to determine the suitability of the filters for denitrification was initiated. Data during this period was included in the denitrification section of this report. A summary of the filter's performance showing the mean values of the data collected and excluding periods of excessive sloughing from the nitrification tower is presented in Table 27. The effects of sloughing and other significant events that occurred during the evaluation period are discussed separately. For the periods presented in Table 27, the overall average wastewater flow rate was

TABLE 27. SUMMARY OF PERFORMANCE OF MIXED-MEDIA FILTRATION SYSTEM

Parameter	Mean Value	Removal - %
BOD_5-mg/l		
Influent	35	---
Effluent	10	71
COD-mg/l		
Influent	56	---
Effluent	36	36
TSS-mg/l		
Influent	22	---
Effluent	6	73
Turbidity-NTU		
Influent	6.1	---
Effluent	2.1	66
Ammonia-mg/l		
Influent	5.9	---
Effluent	5.3	10
Total Phosphorus-mg/l		
Influent	4.7	---
Effluent	4.4	6
Fecal Coliform-#/100 ml*		
Influent	4.75×10^4	---
Effluent	4.28×10^4	10
Flow - mgd	0.47	---
Range (1 Filter)	0.18 - 1.12	---
Range (2 Filters)	0.45 - 1.12	---
Hydraulic Loading-gpm/ft^2	2.02	---
Range (1 Filter)	0.87 - 5.40	---
Range (2 Filters)	1.09 - 2.70	---
Head Loss Rate-ft/hr	0.56	---
Range (1 Filter)	0.009 - 1.31	---
Range (2 Filters)	0.51 - 4.63	---
Backwash Frequency-#/week	9.7	---
Range (1 Filter)	2 - 31	---
Range (2 Filters)	9 - 46	---
Backwash Rate-gpm/ft^2	13.0	---
Backwash Time-min	14.4	---
Backwash Volume-gal	26,096	---

*Expressed As Geometric Mean

mgd x 3785 = cu m/day; gpm/ft^2 x 40.7 = l/min/sq m; ft/hr x 0.3048 = m/hr; gal x 3.785 = l

1780 cu m/day (0.47 mgd). The lowest flows received at the plant typically occurred during the fall, winter and spring. The highest flows occurred during the summer when peak daily flows of 3785 cum/day (1.0 mgd) were received. During the low flow periods, only one of the four filters was in service. For approximately three months during the summer, when the influent flow was typically greater than 2840 cu m/day (0.75 mgd), two filters were utilized. This approach to filter usage resulted in an average hydraulic loading of 82 l/min/sq m (2.02 gpm/ft^2).

The filter backwashing and operating sequence utilized the following procedure: a predetermined maximum filter head-loss (i.e. 3.7 m (12 ft) of H_2O) was set on the filter control panel, and as the head loss reached this level an alarm was sounded. The operator then took that filter off-line for backwashing, and the next filter in the series was placed in service. In this manner all four filters were maintained in an operable condition and were not allowed to be idle along enough to become septic. The filter plugging rate was quantitatively measured in terms of the head-loss rate. The head-loss rate (H/L) was determined by dividing the head-loss (H) by the length of time between backwashes (L). The average head-loss rate was 0.17 m/hr (0.56 ft/hr and varied between 0.06 and 0.21 m/hr (0.2 and 0.7 ft/hr). The frequency of filter backwashing averaged about ten times per week. This evaluation excludes periods where excessive sloughing of solids from the nitrification tower occurred. When the towers were not sloughing, the influent wastewater was typically of high quality which explains the relatively low head-loss rates and long filter runs.

An average backwash rate of 530 l/min/sq m (13 gpm/ft^2) for about 14.5 minutes resulted in the utilization of 100 cu m (26,100 gallons) per backwash. Backwash rates were varied throughout the evaluation period, but no evaluation to optimize rates and minimize backwash volume was completed.

In general, the filters worked well in polishing the effluent from the nitrification towers (influent to the filter). An average 71 percent reduction occurred in BOD_5, while the average reduction in COD averaged 37 percent. A mean reduction of 73 percent for TSS and 66 percent for turbidity was also achieved. Minimal reductions occurred in ammonia, total phosphorus and fecal coliform concentrations.

The trends in filter performance are depicted graphically by the weekly average values for influent and effluent BOD_5 and TSS concentrations shown in Figures 20 and 21, respectively. For the first five months of the evaluation (i.e. through March, 1977) consistent BOD_5 and TSS removals were achieved through the filters with concentrations in the filter effluent averaging 5 mg/l and 4 mg/l, respectively. During this period one filter was in service and the hydraulic loading was approximately 70 l/min/sq m (1.7 gpm/ft^2). For the next two months until a portion of the plant was bypassed for modification in June, some deterioration in effluent quality occurred. The mean TSS concentration in the effluent increased to 7 mg/l, and the BOD_5 level increased to 11 mg/l. During this time only one filter was in service, yet plant flow had increased significantly. The hydraulic loading to the mixed media filter was increased by about 60 percent, to 110 l/min/sq m (2.7 gpm/ft$_2$). This higher hydraulic loading was felt to be the major factor that contributed to the slightly deteriorated effluent quality.

The activated sludge aeration basins were bypassed for two weeks in June 1977, to modify the gate separating the activated sludge basins. When the plant was placed back in operation in July, two filters were put on line to handle the high summer flows. With the two filters in service, the hydraulic loading still averaged 102 l/min/sq m (2.5 gpm/ft^2) for the months of July and August, 1977. However, the filter influent TSS and BOD_5 concentrations increased to 38 mg/l and 118 mg/l, respectively, which were the highest levels reached during the total evaluation period. Much of the BOD_5 was in soluble form which was a result of trying to "start-up" the activated sludge process during the high summer flow period. It should also be noted that during this time a higher than normal strength sewage was being received at the plant due to contributions of waste from the dump station, including septic tank and chemical toilet waste. The filters performed well in removing the suspended solids; however, the backwash frequency increased to a high of 46 times per

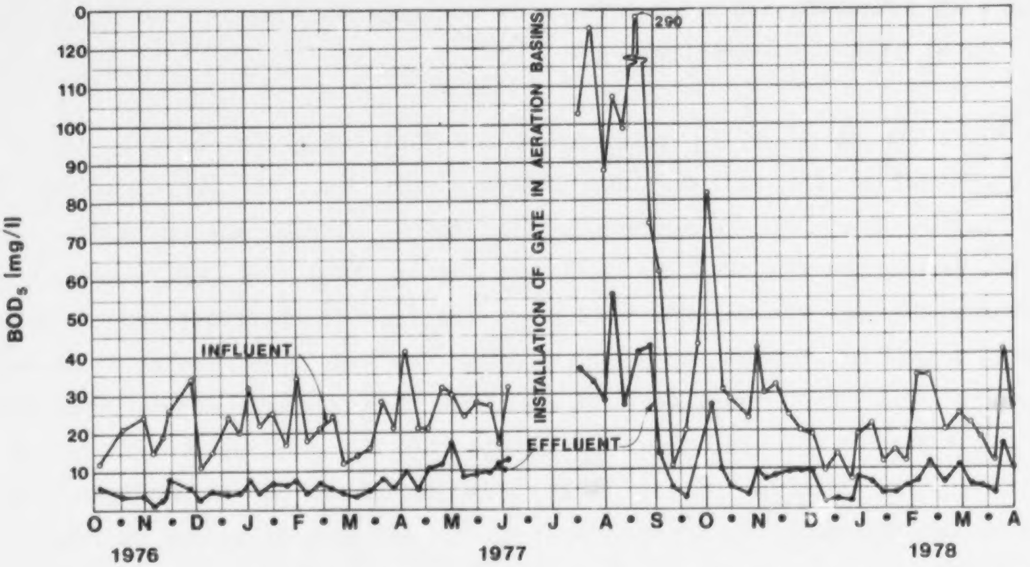


Figure 20. Mixed media filter influent and effluent BOD_5 concentration during the research project.

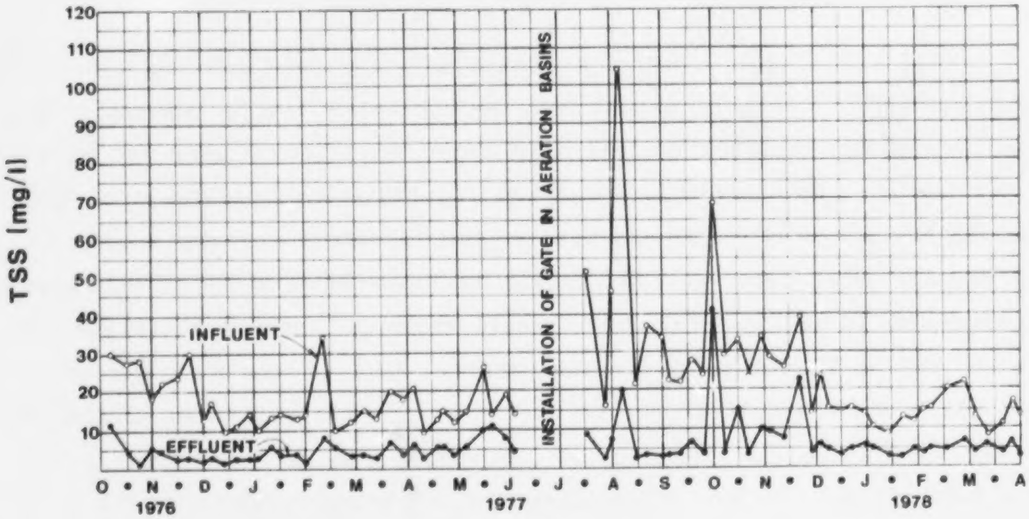


Figure 21. Mixed media filter influent and effluent TSS concentration.

week which was considerably greater than the average frequency of 10. The BOD_5 removal was not nearly as good as the TSS removal.

Also during the summer of 1977, sloughing of the biological mass from the nitrification tower media (plastic media was in service) occurred in quantities that resulted in almost immediate plugging of the filters. Typically when a period of sloughing occurred the biological mass from the tower would plug a filter within 10 minutes and another filter would have to be put on line. These extremely low filter run times required frequent backwashing which depleted the volume of backwash water. When all of the filters were plugged or when the volume of backwash water was depleted, the nitrification and filtration systems were bypassed. A change in tower operation to provide for a more constant hydraulic loading allowed the sloughing problem to become less severe, but the problem was not eliminated. It was concluded that with the occurrence of tower sloughing, the filters could not be depended on for solids removal. This conclusion is significant when considering a design for a solids capturing process following an attached growth nitrification system. It is noted that a similar plugging problem occurred with the filters when activated sludge solids were lost from the final clarifier. An overall conclusion was that the mixed media filters worked very well to polish the normal effluent of the upstream processes, but was not suitable during periods of process upset or tower sloughing. A sedimentation basin may be more effective during periods of upset such as sludge bulking or solids sloughing. To this end, a possible design consideration for the UTSD facility would be to combine the function of the tower wet-well with that of an overflow clarifier. With this option available the heavy solids could be removed by a sludge collector mechanism, thus eliminating the filter's rapid plugging problem.

From September 1977, until the end of November 1977, the TSS and BOD_5 concentration of the influent to the filters averaged 33 mg/l and 32 mg/l, respectively, which were lower than the summer loadings. Respective concentrations in the effluent were to 9 mg/l and 12 mg/l. The mean hydraulic loading also decreased to 65 l/min/sq m (1.6 gpm/ft^2). The decreased loading allowed the frequency of backwashing to return to more reasonable values, averaging once per day.

From December, 1977, until April, 1978, consistent TSS removal was achieved across the filter. The mean TSS concentration in the effluent during this period was 4 mg/l. BOD_5 values in the effluent were more sporadic, but the mean concentration was still only 6 mg/l. At the same time the lowest average head loss rate was achieved during the project at 0.07 m/hr (0.22 ft/hr). This value is approximately half of the rate that existed during the previous winter of 1977. As noted by the TSS graph in Figure 21, the influent solids concentrations and effluent quality were almost identical for these two winter periods. The major difference between the 1978 and 1977 winter filter head-loss rate was associated with the operation of the activated sludge system. As previously discussed, a higher mass was held in the activated sludge system during the 1978 winter, which resulted in improved BOD_5 removal. The sludge characteristics associated with the two levels of activated sludge system mass apparently were responsible for different forms of effluent suspended solids, and consequently different head-loss rates through the filters.

In conclusion, the mixed media filters normally worked well to polish the UTSD plant effluent. However, during periods of heavy sloughing from the nitrification tower or periods of solids loss from the activated sludge clarifier bypassing of the filters was required.

OZONE DISINFECTION

General

The ozone disinfection system was not run continuously during the two-year data collection phase of the research project, because several system modifications were necessary before safe, continuous operation could occur. The system was operational on a periodic basis, and during portions of the two-year data collection phase of the research project separate special studies were completed to evaluate the performance, design and cost aspects of the system's operation. This section of the report describes the results of the special studies.

Data collection for the ozone system special studies included chemical and microbiological analyses, ozone in air concentrations and mass measurements, ozone in water-concentration measurements, electrical power consumption measurements and other miscellaneous measurements. Since the use of ozone in wastewater treatment is a relatively new application, the equipment and procedures used to collect the ozone data are described.

Data Collection

Ozone in Air - Concentration and Mass Measurements--

The ozone concentration in the ozone/air flow from the generators was measured by a wet chemistry procedure and by a high concentration continuous reading ozone meter (Dasibi High Concentration Ozone Meter, Model 1003-AH). The wet chemistry method involved a sodium thiosulfate titration of a prepared solution of potassium iodide which had been exposed to a known volume of the ozone/air flow stream. A detailed description of the testing and data recording procedures is included in Appendix G.

An alternate acceptable method of monitoring ozone concentration in air was available after the Dasibi continuous reading ozone meter was properly set-up and calibrated. Originally, meter readings did not correlate with wet chemistry results. The problem was isolated to the ozone/air and purge air flow rate to the meter. Lowering and controlling the ozone/air and purge air flow rates to about 2 l/min resulted in consistant meter readings that correlated well with wet chemistry results. A comparison of meter results with wet chemistry results is shown in Table 28 and Figure 22. Due to the good correlation between wet chemistry and Dasibi meter results, it was concluded that the Dasibi meter could be used to determine the ozone in air concentrations so that additional data points could be less tediously obtained. However, the Dasibi meter was used to obtain only about 25 percent of the ozone/air concentration measurements used in this report, because the problem with the meter was not corrected until the later part of the research evaluation.

TABLE 28. SUMMARY OF COMPARISON OF CONTINUOUS MEASUREMENT DASIBI OZONE METER RESULTS WITH WET CHEMISTRY RESULTS

Date	7/19/78	7/21/78	7/25/78
Dasibi Meter Span Setting	80570	80570	80570
Number of Tests	4	9	5
Average Wet Chemistry* Result (ppm(vol))	5598	5372	3222
Average Actual Dasibi* Reading (ppm(vol))	5532	5351	3204
Average Difference (%)**	0.1	0.4	0.6
Range of Difference (%)	-0.2 to 2.0	-0.7 to 2.6	-0.7 to 1.7

*Corrected to standard conditions of 1 atmosphere pressure and 25°C temp.

$$\text{**Percent Difference} = \frac{(\text{Wet Chemistry} - \text{Actual Dasibi})\ (100)}{(\text{Wet Chemistry})}$$

The ozone/air concentration was combined with the generator air flow to obtain the mass of ozone produced. The generator air flow was measured with a Fischer and Porter Series 10A3500 "Flowrator" meter. The recorded flow was corrected to standard pressure and temperature conditions of one atmosphere and 25°C.

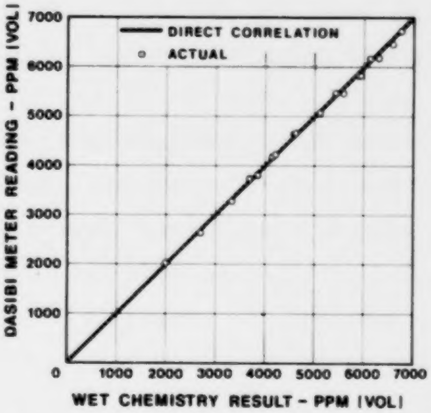


Figure 22. Comparison of Dasibi meter and wet chemistry ozone/ air concentration measurements.

The ozone/air concentration of the contact basin off-gas was measured using a wet chemistry procedure. A detailed description of the testing and data recording procedures is included in Appendix H. The flow rate of off-gas through the vent duct was measured using a pitot tube. The pitot tube was not ozone resistant so the off-gas flow rate determinations were made with the ozone generator shut down and only the air pretreatment system running. Off-gas flow measurements were taken at different air flow rates from the air pretreatment unit. The data points were very reproducible and a curve was developed relating off-gas flow rate to air flow rate from the ozone generation system. The curve was used to determine off-gas flow rate during testing of the ozone disinfection system. (See Table H-2 of Appendix H). The off-gas flow rate, corrected to standard conditions, was coupled with the off-gas concentration and was used to obtain the mass of ozone contained in the contact basin off-gas.

Ozone In Water - Concentration Measurements--

Ozone residual concentrations in the effluent from the ozone contact basin were initially made using a volumetric titration procedure. Using this procedure it became apparent that the color change at the end of the titration was nearly impossible to detect. It was decided that an amperometric titration method would be employed. An amperometric titrator was purchased and was used to obtain ozone/water concentrations. During the research evaluation period, good disinfection results were often obtained with no detectable or negligible ozone residuals.

Electrical Power Consumption Measurements--

Ozone generator and air pretreatment power consumption measurements were made with a Sangamo type S3DS watt-hour meter, which was tied into the electrical feed lines to both the ozone generator and air pretreatment units. The meter provided the capability to determine totalized kilowatt-hour readings, maximum kilowatt demand readings and instantaneous kilowatt demand readings. A sample of the data sheet used to record test information and calculate power requirement values is included in Table G-2 of Appendix G.

Miscellaneous Measurements--

Other measurements and gauge readings were taken in conjunction with generator production determinations as shown in Table G-2 of Appendix G. The air pretreatment dew point was measured with a Shaw Model "S" Mini Hygrometer which had a Red Spot probe. Using the meter, the changes in air dew point from the air pretreatment system were recorded throughout the day. The air dew point as measured by this procedure typically ranged from -70°C to -54°C. (Note: new information developed in March, 1979 indicated that these results were inaccurate. The magnitude and impact of the inaccurate readings on the results are presented at the end of this section.

The air compressor seal water pressure reading was recorded daily and also every time ozone generator production testing was conducted. The seal water pressure was the line pressure of the water that entered the water ring seal. The pressure gauge was located before a filter screen in the water supply line. When the in-line filter screen became plugged, varying seal water pressure indicated the varying water flowrate to the seal. A variable flowrate affected the compressed air temperature, which in turn affected power consumption of the refrigerant drier.

Data Evaluation and Discussion

The discussion of results from the research evaluation of the UTSD ozone disinfection system is separated into four general categories: ozone generation, ozone system power requirements, ozone contacting system and disinfection performance.

During the UTSD research evaluation the ozone disinfection system was intermittently operated. Intermittent operation resulted from numerous problems requiring design or operations changes. Several of the problems encountered were associated with the "state of the art" design of one of the first full-scale ozone wastewater disinfection systems in the United States. Much conflicting and confusing information was provided by various "ozone experts" in regard to the UTSD ozone disinfection system. The conflicting information provided often delayed the correction of the design and operational problems encountered. The major disadvantage of the intermittent operation of the ozone disinfection system was that a thorough evaluation of disinfection performance was not achieved.

Ozone Air Pretreatment--

The three components of the ozone generation system were air pretreatment, ozone generator and power supply. These three areas were evaluated both separately and in combination during the course of the research effort. The ozone generation system performance was dependent upon good quality dry air. As such, the operation and performance of the air pretreatment system was just as important as the operation and performance of the generator itself.

Several problems were encountered with the air pretreatment system and the potential for some problems to reoccur exists. Steps are being taken to eliminate this potential.

The air compressor for each air pretreatment system was a constant speed unit and continuously discharged an air flow of 160 cu m/hr (94 scfm). By bleeding-off excess air, the air pretreatment system could operate at variable air flow rates. Originally, excess air from the compressor was bled-off after passing through the air drying tower. Each drying tower was rated at a maximum air flow of only 130 cu m/hr (78 scfm), thus was constantly overloaded. This caused an excessive high dew point of the "dried" air. Subsequently, a minor modification was made by installing a bleed-off valve after the air compressor and before the air drying tower so that excess air was bled-off before the air drying tower. Varible air flow not to exceed the air pretreatment system's ability to provide dry air is highly desirable, but a more economical means of providing variable air flow is required.

Compressed air was directed through a refrigerant drier that had an input voltage of 440 volts. This voltage was compatible with the voltage to the ozone generator, but when operational problems were encountered with the refrigerant drier it was quickly learned that all parts locally available were for 220 volt refrigeration units. These parts were not suitable for the installed 440 volt refrigerant drier, and parts had to be special ordered which delayed the unit's repair. The time delay for repair of the refrigerant drier was the main reason Generation System No. 1 was not operable during most of the time the production data used for this report was developed. To maintain both ozone generation systems fully operational, the UTSD will have to purchase additional spare parts for the refrigerant driers. Also, the UTSD staff was not trained nor had the necessary equipment to repair the refrigerant unit. The corrective maintenance and spare parts problems encountered with the UTSD 440 volt refrigeration system should be considered during the design of air pretreatment capability for other ozone systems.

Each of the two air drying towers contained activated alumina, molecular sieves and alumina balls desiccant material to absorb the water in the air and lower the dew point to less than -51°C. One tower "dried" air from the compressor while the other tower was regenerated by a combination of heating the desiccant material to release the bound water and purging the tower contents with dry air to remove the excess moisture. The towers were cycled for drying and regeneration at 8-hour intervals.

Generally, the air drying towers worked well after the air bleed-off valve was moved to a location in the air flow scheme which was prior to air entering the towers. However, "sticking" occurred in the linkage of the pneumatically operated switching mechanisms used to alternate the towers from the drying to regeneration cycles. The linkage was lubricated, but the potential for this problem to reoccur still exists. The signal for cycling the drying towers is electrical while the tower switching mechanism is pneumatic. If problems are encountered with the pneumatic switching mechanism, the electrical system will still indicate that the towers are functioning normally even though "wet" air could be passing through the tower that is regenerating. If this occurrs, excessive moisture could be directed to the ozone generator. Under this condition the ozone generator could be "flooded". The term flooded is used to describe moisture build-up in the ozone generator which causes short-circuiting and can cause electrode tube and/or fuse failure.

On several occasions flooding of the ozone generator did occur. Once flooding occurred due to a problem with the refrigerant drier. The refrigerant drier motor overheated and burned out, for an as yet unknown reason. A new refrigerant drier was ordered. When received, careful electrical checks were made during its installation to try to isolate the problem.

Flooding of the ozone generator on three other occasions has been tentatively associated with problems of variable seal water pressure to the water ring air compressor. These generator floodings were expensive because several electrode tubes and fuses blew out. The greater the seal water pressure the greater the water flow rate through the compressor and the lower the temperature of compressor air. The temperature of the compressed air was important because if the temperature was too high the refrigerant drier could not cool the air to reduce the dew point and the air drying tower was overloaded. The flooding problems were believed to have occurred due to plugging of an in-line filter screen which was used to remove any particulate matter from the water that was directed to the compressor. Plugging caused the flow of water to the compressor to decrease and the temperature of the compressed air to increase and eventually led to overloading of the drying tower. The entire seal water supply system is being re-evaluated to determine what design modification or preventive maintenance checks can be instituted to reduce the frequency and/or effects of the screen plugging problem.

Although sources of ozone generator flooding problems have been isolated, the potential of flooding still exists. It appears that a high dew point alarm and an associated automatic generator shut-off is necessary to prevent the expense and loss of production associated with generator flooding. Originally, the relative air dew point was monitored with cobaltous chloride color changing indicator. This indicator was inadequate as an alarm or protection device for the ozone generator for two reasons: 1) Someone had to see the color change and shut down the system before flooding occurred and 2) the color change was not sensitive to gradual changes in dew point so potential problems could not be detected until they were quite far along.

A dew point indicator was purchased as part of the research project to obtain more exact information on air dew point versus generator production. This indicator has greatly aided in the detection of changes in dew point and correction of problems before flooding of the generator occurred. However, the potential for generator flooding still exists since operator observations of the indicator on a continuous basis is still required to detect any problems. As a better solution, a high level dew point alarm and associated automatic generator shut-down is being considered. To date, this would have saved the UTSD at least $1,600 in electrode tubes and fuses during the past two years of operation.

Ozone Generator Production--

Many parameters can influence the rate of ozone production including: power supply, air dew point, ozonated air temperature which is influenced by the volume of air directed through the generator and the ozonated air heat removal capability of the cooling water jacket. These items are not all inclusive, but were selected for analysis because they represented those items within the realm of operational control for the UTSD system.

The UTSD ozone generators were designed to supply ozone at a rate of 34.3 kg/day (76 lb/day) at an air flow of 118 cu m/hr (70 scfm). The ozone production for Generation System No. 2 only is discussed, because Unit No. 1 was not operational. The production rate for different air dew point levels will be presented because the ozone production rate decreased as the dew point of the air increased. This change in production may be a significant operational consideration with respect to continuous, satisfactory effluent disinfection. The production rate will also be compared to the relative power setting of the generator for two different air flow rates, namely the design air flow rate of 118 cu m/hr (70 scfm) and a lower air flow rate of 79 cu m/hr (47 scfm).

The air dew point readings increased proportionately to the drying tower operating time. Typically, soon after a regenerated tower came on-line and began drying, the air dew point reached its lowest level. As the tower dried more air, the dew point increased. Apparently, as the desiccant absorbed and contained more and more moisture, less moisture was absorbed as indicated by the dew point readings. The rate of increase of the dew point was greater at the design air flow rate of 118 cu m/hr (70 scfm) than at the lower air flow rate of 79 cu m/hr (47 scfm). The changes in air dew point for the two air flow rates versus drying tower operating time is shown in Figure 23.

The drying time per operating cycle for each tower was eight (8) hours. The lowest dew point reading shown in Figure 23 is -72°C., although readings as low as -74°C were achieved. The highest dew point recorded was -54°C. All dew point levels recorded, except when obvious air pretreatment problems were noted to cause generator floodings, were better than the manufacturer's rated minimum dew point level of -51°C. The UTSD ozone air pretreatment system functioned very satisfactorily.

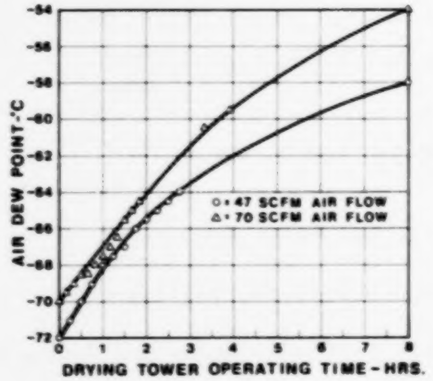


Figure 23. Change in air pretreatment dew point with drying tower operating time (scfm x 1.70 = cu m/hr.)

The change in ozone production per degree of change in dew point was evaluated at different generator power settings. Two power settings were evaluated and results are shown in Figure 24 and in Table 29. In general, the ozone production level decreased as the air dew point increased, even though the manufacturer's rated dew point level of -51°C as measured by the dew point indicator was achieved throughout the drying cycle.

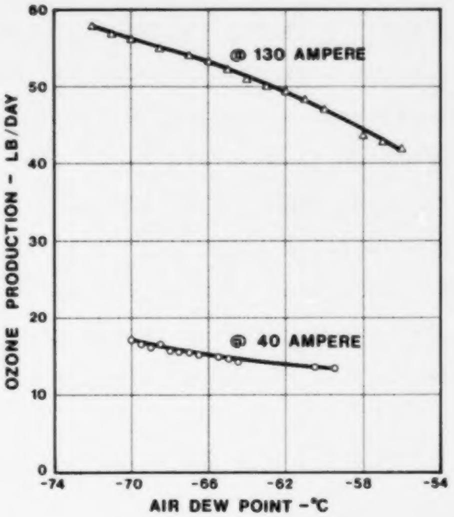


Figure 24. Change in ozone production with dew point at two generator power settings (lb/day x 0.454 = kg/day).

As shown in Table 29, the mass decrease in ozone production per degree change in dew point was about three times greater for the 130 amp power setting than for the 40 amp setting. However, the percentage change was slightly less for the 130 amp setting at 1.70%/°C. than for the 40 amp setting of 1.93%/°C. From the data presented it was shown that

TABLE 29. EFFECT OF DEW POINT AND POWER SETTING ON OZONE PRODUCTION

Dew Point	130 Ampere	40 Ampere
Maximum Production - 72°C.	57 lb/day	---
- 70°C.	---	17.1 lb/day
Minimum Production - 56.5°C.	42 lb/day	---
- 59.5°C.	---	13.6 lb/day
Total Dew Point Increase	15.5°C.	10.5°C.
Ozone Production Decrease	15 lb/day	3.5 lb/day
Specific Ozone Production Decrease		
Mass Decrease	0.97 lb/day/°C.	0.33 lb/day/°C.
Percent Decrease	1.70%/°C.	1.93%/°C.

lb/day x 0.454 = kg/day

ozone production decreased considerably with a decrease in dew point, which is important with respect to ozone dosage to the wastewater. The implications of these findings on design and operation are significant.

At the UTSD plant the wastewater flow rate was controlled through a flow equalization basin and a negligible variation in daily plant flow occurred. The ozone dosage to the effluent was manually controlled by adjusting the generator power setting. However, at a given power setting the ozone dosage decreased as the dew point increased. The potential magnitude of the decrease in ozone dosage for observed changes in air dew point is summarized in Table 30.

TABLE 30. POTENTIAL DECREASE IN OZONE DOSAGE FOR OBSERVED CHANGES IN AIR DEW POINT (CONSTANT GENERATOR POWER SETTING AT 130 AMPS)

	Air Dew Point* -72°C.	Air Dew Point -56.5°C.
Wastewater Flow (mgd)	1.37	1.37
Ozone Dosage		
(mg/1)	5.0	3.7
(1b/day)	57**	42**

mgd x 3785 = cu m/day; lb/day x 0.0189 = kg/hr.
*The manufacturer's minimum rated dew point level was -51°C.

As shown in Table 30, the ozone dosage could vary from 5.0 to 3.7 mg/l if the air dew point changed from -72 to -56.5°C (a change that was observed during a typical drying cycle). A change in dosage because of dew point is important from a design and operation basis because disinfection performance is influenced by ozone dosage. Therefore, ozone production information at different power settings and at variable dew point levels are required in order to properly design and operate ozone disinfection systems. In the final analysis it may be required that ozone systems be designed with multiple units which have the air pretreatment drying towers changed sequentially so as to reduce the overall effect of a rise in dew point on ozone production.

It should be noted that the sensitivity of the system disinfection capability to ozone dosage was not evaluated due to the intermittent operation of the UTSD ozone system. It may be that an ozone dosage between 3.7 and 5.0 mg/l yields the same general disinfection level, especially when other system variables like effluent COD, TSS and fecal coliform concentrations are considered. If the disinfection capability is not overly sensitive to this range of dosages the dosage variation because of dew point would not be as critical. This aspect should be further evaluated. However, it is still concluded that more information should be developed by ozone manufacturers on ozone production versus dew point levels and ozone production versus generator power settings in order to provide design engineers and plant operators with a better basis for ozone system design and operation.

The major factors affecting ozone production are generator power setting, air dew point and ozonated air temperature, which is influenced by the air flow rate to the ozone generator and the heat removal capability of the cooling water jacket. The cooler the temperature of the ozonated air, the less rapid ozone will be decomposed after it is generated. The UTSD ozone generator begins producing ozone at a consistant, reproducible level at a power setting of 40 amps. The maximum power setting tested was 150 amps, when the generator voltage was 450 volts. For the production evaluation the mass of ozone produced was determined for power settings at 10 amp intervals between 40 and 150. The ozone production values shown in this report were taken when the air dew point was between -70°C. and -74°C as indicated on the Shaw meter. This dew point level represented the best condition for ozone production within the limits of the air pretreatment unit.

To insure that the cooling water system was performing at optimum conditions, the cooling water jacket was inspected for possible scaling which could have reduced its heat removal effectiveness. No scaling was noted at cooling water jacket sites that were inspected. This was as expected because no scaling problems were encountered on other equipment in the plant that used the same water supply. The temperature of the cooling water ranged between 10°C and 12°C, which was within the ozone manufacturer's specifications.

The actual temperature of the ozonated air was not recorded. However, the relative temperature of the ozonated air was investigated within the limits of the UTSD system by adjusting the air flow rate to the generator. The design air flow rate of 118 cu m/hr (70 scfm) was expected to develop the lowest ozonated air temperature, and in turn produce the highest mass of ozone at a given power setting. The lower air flow rate of 79 cu m/hr (47 scfm) was expected to produce a lower mass of ozone, especially at the higher power settings. The ozone production levels for the two air flow rates is shown in Figure 25. As shown, ozone production is nearly the same for both air flow rates at all generator power settings, although the higher flow rate generally had a slightly higher ozone production level. Apparently, the ozone air temperature change and hence ozone production was not significantly affected within the range of air flow rates capable for the UTSD system. The fact that little production difference was shown for the lower air flow rate is significant, because a smaller and/or slower speed air compressor could have been used which would have resulted in an electrical power savings.

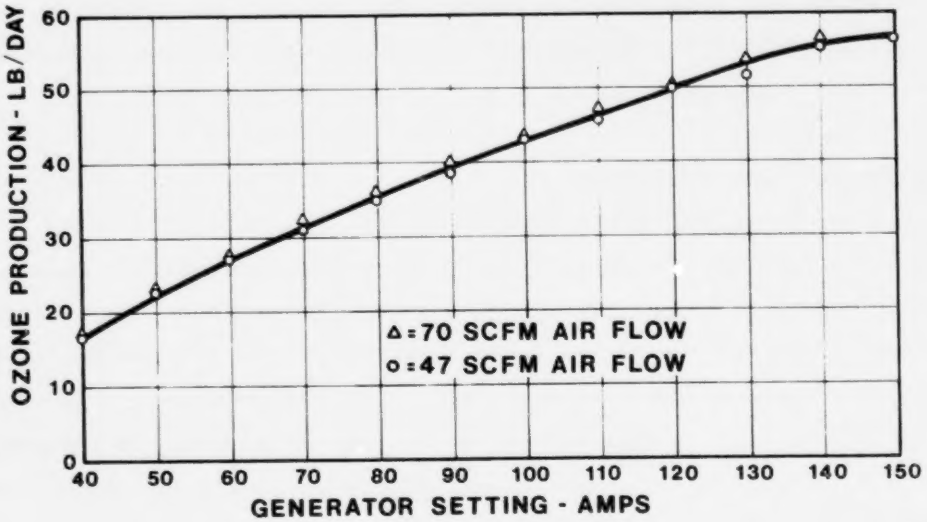


Figure 25. Ozone generator production at various generator power settings (lb/day x 0.0189 = kg/hr); (scfm x 1.70 = cu m/hr).

The ozone production levels shown in Figure 25 ranged from 7.7 kg/day (17 lb/day) to 26 kg/day (57 lb/day), and a fairly uniform increase in production occurred for each 10 amp increase of the power setting. The maximum ozone production level was 26 kg/day (57 lb/day). This occurred at the air flow rate of 79 cu m/hr (47 scfm). The maximum amp setting was not tested at the design air flow rate of 118 cu m/hr (70 scfm), because the ambient ozone concentration within the building became too high on that test day and the ozone generator was shut down.

The maximum ozone production level of 26 kg/day (57 lb/day) at 79 cu m/hr (47scfm) air flow was 25 percent less than the manufacturer's rated value of 34 kg/day (76 lb/day). Based on comparable results for other amp settings, it is not expected that the ozone production level at the design air flow of 118 cu m/hr (70 scfm) would be significantly higher. The reason for the lower than design ozone production level was not known and is still being investigated. All known influences on ozone production were optimized during the ozone production tests, including lowest achievable air dew point as measured by the Shaw meter and clean (no scaling) water jacket. Also, prior to production testing the generator was thoroughly cleaned, all electrode tubes were removed and checked for damage, and all tubes were replaced according to the manufacturer's recommendations.

Ozone System Power Requirements--

One of the advantages considered in the selection of ozone for the UTSD plant was on-site production. On-site production capabilities were felt to be desireable when compared to chlorine and dechlorination chemical costs and chemical hauling in the canyon roads which led to the plant. The initial cost of the ozone generation equipment and the anticipated power costs associated with the continuous generation of ozone were considered in this selection. During the research, an evaluation of the ozone generation power requirement was made to determine if the initial cost assumptions were adequate.

The UTSD ozone system has been intermittently operated, and the typical operating procedure was to dose at a rate to insure disinfection. No attempt was made to optimize ozone dosage. As such, realistic values for power required to generate adequate ozone to achieve disinfection were not obtained. However, power consumption over the operating range of the ozone generating system were determined (i.e., ozone generation "mapping"). Each major unit of the ozone system were separately evaluated. Presently, power is consumed by the air pretreatment system, by the cooling and seal water system, and by the ozone generation process. In the future, an ozone destruct unit for the contact basin off-gas will add to the power consumption.

Power consumption for the air pretreatment system included power for the air compressor, refrigerant drier, air drying tower heater, pneumatic control system air compressor, and electrical control circuit. The power requirements for the air compressor, refrigerant drier and air drying tower heater were most significant. The power requirement for the pneumatic control system air compressor and electrical control circuit were insignificant in terms of total power usage, and were not included in the power consumption evaluation.

The air compressor operated continuously and used 8.35 kW of electrical energy. The air compressor was designed to provide a nominal 118 cu m/hr (70 scfm) air flow to the ozone generator. As described, the unit discharged 160 cu m/hr (94 scfm) of air, and the excess air had to be bled-off to avoid overloading the air drying tower. It was also determined that generator production did not significantly change from an air flow rate of 118 cu m/hr (70 scfm) to a lower rate of 79 cu m/hr (47 scfm).

The instantaneous power consumption of the refrigerant drier was 2.0 kW. However, a lower average daily power consumption was determined because the drier operating time varied with the inlet air temperature and air flow rate to the drier. As described, inlet air temperature increased as the air compressor seal water pressure decreased. Generally, the average inlet air temperature was about 33°C. The relationship between the refrigerant drier operating time and inlet air temperature for an air flow rate of 79 cu m/hr (47 scfm) is shown in Figure 26. At an inlet air temperature of 33°C., the average refrigerant drier operating time was 11.1 hrs/day. A similar evaluation for the higher flow rate of 118 cu m/hr (70 scfm) indicated an average operating time of 14.4 hr/day. These operating times were coupled with the 2.0 kW instantaneous power consumption to determine the average daily power requirements of the refrigerant drier.

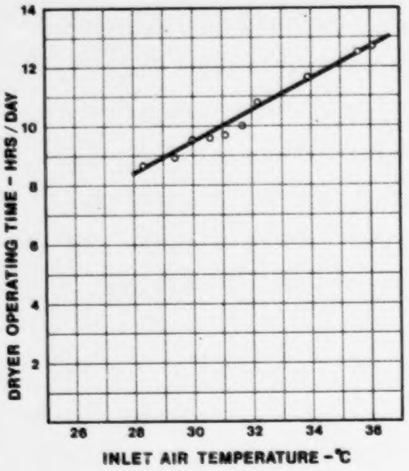


Figure 26. Refrigerant drier operating time at various inlet air temperatures and an air flow rate of 79 cu m/hr (47 scfm).

The air drying tower used electrical energy in the tower regeneration cycle. During regeneration the tower was heated by an electrical heater that had an instantaneous power requirement of 3.65 kW. The 8-hour regeneration cycle consisted of tower "heating" for 4 hours and "cooling" for 4 hours. During the 4-hour heating cycle, heater operation was controlled by a high temperature cut-off and a lower temperature start-up system. Therefore, actual heater operating time was less than the total 4 hours. The average heater operating time per heating cycle was determined to be 3.25 hours, resulting in a daily average electrical usage of 1.48 kW.

One other use of power for the ozone system was supply water for ozone generator cooling and for air compressor operation. This water was provided by the plant potable water pumping system. A special power consumption measurement taken to determine the power usage of the potable water system indicated that the average daily power consumption was 2.2 kW. The potable water demand for the ozone generation operation was about 95 percent of the total plant potable water usage. Therefore, the power required to supply water to the ozone generation system was 2.10 kW.

Air pretreatment power consumption data is shown in Table 31. The daily average power consumption for the air compressor and air drying tower heater was not affected by air flow rate. Power consumption of the refrigerant drier was affected by air flow rate. However, the net effect was that the daily average power consumption was not significantly different for the two air flow rates.

TABLE 31. SUMMARY OF POWER CONSUMPTION FOR THE AIR PRETREATMENT AND COOLING WATER UNITS

Unit	Instantaneous Power Consumption (kW)	Daily Average Power Consumption @47 scfm (kW)	Daily Average Power Consumption @ 70 scfm (kW)
Air Compressor	8.35	8.35	8.35
Refrigerant Drier	2.00	0.93*	1.20*
Air Drying Tower	3.65	1.48**	1.48**
Cooling and Seal Water	5.00	2.10***	2.10***
TOTAL	----	12.86	13.13
		USE 12.9	USE 13.1

scfm x 1.70 = cu m/hr.

*Refrigerant Drier on-time at an average inlet air temperature of 33°C.

**Average drying tower heater on-time of 3.25 hours per 8-hours cycle.

***Average potable water pump on-time of 10.5 hours. (95% of potable water used for cooling and seal water).

The power requirement of the ozone generator increased as the level of ozone production increased. The most important consideration was the power required to produce a given mass of ozone (i.e., power utilization in terms of kWh/lb). Two different air flow rates were used in determining generator power utilization, and power consumption measurements were taken at 10 amp intervals starting where reliable and reproducible ozone production began (40 amps) and were continued to the generator's maximum setting (150 amps).

Power consumption for the ozone generator had to be carefully determined because power consumption measurements for the air pretreatment and the generator were combined in the readings obtained from the single ozone system watt-hour meter. In order to attain the power consumption for the ozone generator the power consumed by the air pretreatment units that were operating at that time was subtracted from the total measured ozone system power that was indicated by the watt-hour meter. Using this procedure, reproducible ozone generator power consumption values were obtained.

The ozone generator production, power consumption and power utilization values for the two evaluated air flow rates are shown in Table 32. Generator power consumption varied from a low of 4.4 kW to a high of 25.1 kW as the generator amperage setting increased. Ozone production also increased as the amperage increased, but at a lesser rate than power consumption as evidenced by the increase in power utilization. Power utilization increased from a low of 13.7 kWh/kg (6.2 kWh/lb) to a high of 23.6 kWh/kg (10.7 kWh/lb), which is graphically illustrated in Figure 27.

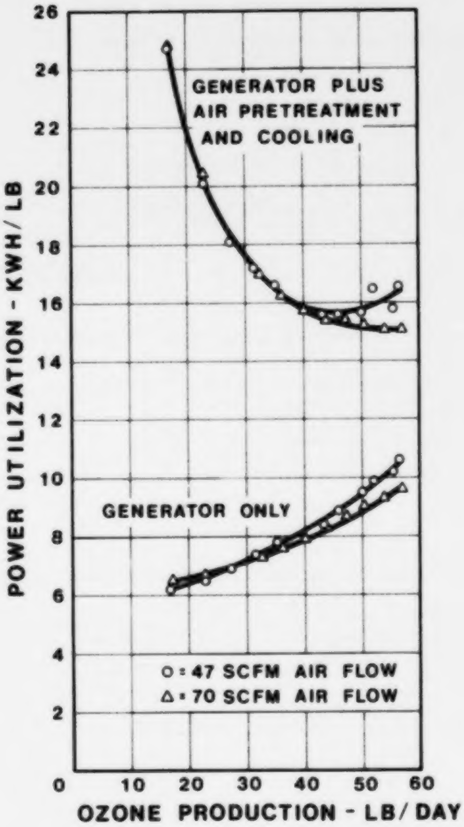


Figure 27. Measured power utilization for the existing UTSD ozone generation system (scfm x 1.70 = cu m/hr; lb/day x 0.454 = kg/day, kWh/lb x 2.21 = kWh/kg).

The power utilization values shown in Table 32 for Ozone Generator No. 2 were obtained under conditions that would yield maximum ozone production. These conditions include: air dew point equal to or less than -70°C as measured by the Shaw meter, all electrode tubes operational, negligible scaling of the cooling water jacket and a recently cleaned ozone generator. It should be noted that a series of power utilization measurements were taken before Generator No. 2 was cleaned. The uncleaned generator power utilization was an average 15 percent greater than values that are presented for the cleaned generator.

A summary of the total ozone system power requirements for each air flow rate evaluated is shown in Table 33 and 34. The power utilization values for the two air flow rates were compared graphically in Figure 27. As shown, power utilization for the two air flow rates was not significantly different. Apparently, the difference in air flow rates which represented a fairly broad

TABLE 32. OZONE GENERATOR POWER REQUIREMENTS

	Ozone Production		Ozone Generator Power Consumption		Ozone Generator Power Utilization	
Amperage (ampere)	@ 47 scfm (lb/day)	@ 70 scfm (lb/day)	@ 47 scfm (kW)	@ 70 scfm (kW)	@ 47 scfm (kWh/lb)	@ 70 scfm (kWh/lb)
40	16.8	17.1	4.4	4.6	6.2	6.5
50	22.8	22.9	6.2	6.4	6.5	6.7
60	27.4	----	7.8	---	6.9	---
70	31.5	32.5	9.7	9.9	7.4	7.3
80	35.1	36.2	11.4	11.4	7.8	7.6
90	----	40.0	----	13.1	---	7.9
100	43.1	43.9	15.1	15.1	8.4	8.3
110	45.9	47.2	17.0	17.2	8.9	8.7
120	50.0	50.3	19.7	18.8	9.5	9.0
130	51.8	53.9	21.4	20.8	9.9	9.3
140	55.4	56.8	23.5	22.6	10.2	9.6
150	56.3	----	25.1	----	10.7	---

scfm x 1.70 = cu m/hr; lb/day x 0.454 = kg/day; kWh/lb x 2.21 = kWh/kg.

flow range for the UTSD ozone system was not great enough to affect a change in power utilization.

The power utilization values for the UTSD ozone generator were at least 30 percent greater than expected power utilization figures. The major reason for the higher power utilization was lower than design ozone production rates. The maximum ozone production rate was only about 75 percent of the manufacturer's rated capacity. If the UTSD ozone generator had been achieving its rated ozone production levels at existing power consumption rates, the resulting power utilization values would have been much lower as shown in Figure 28. Efforts to achieve a lower power utilization for the UTSD ozone generators are still being conducted.

The relatively high values for power utilization observed for the UTSD ozone generation system can hopefully be reduced, but it is not expected that a change would occur that would dramatically alter the shape of the total power utilization curve as shown in Figure 28. The shape of the observed and equipment specification power utilization curves indicates that dramatically

TABLE 33. TOTAL OZONE SYSTEM POWER REQUIREMENT AT AN AIR FLOW OF 79 CU M/HR (47 SCFM)

Generator Power Setting (ampere)	Ozone Production (lb/day)	Power Consumption Generator (kW)	Power Consumption Support Systems (kW)	Total (kW)	Power Utilization (kWh/lb)
40	16.8	4.4	12.9	17.3	24.7
50	22.8	6.2	12.9	19.1	20.1
60	27.4	7.8	12.9	20.7	18.1
70	31.5	9.7	12.9	22.6	17.2
80	35.1	11.4	12.9	24.3	16.6
90	----	----	----	----	----
100	43.1	15.1	12.9	28.0	15.6
110	45.9	17.0	12.9	29.9	15.6
120	50.0	19.7	12.9	32.6	15.6
130	51.8	21.4	12.9	34.3	15.9
140	55.4	23.5	12.9	36.4	15.8
150	56.3	25.9	12.9	38.8	16.5

*Air Compressor = 8.35 kW, Refrigerant Drier = 0.93 kW, Air Drying Tower Heater = 1.48 kW and Cooling Water Pumping = 2.10 kW.

TABLE 34. TOTAL OZONE SYSTEM POWER REQUIREMENT AT AN AIR FLOW OF 118 CU M/HR (70 SCFM)

Generator Power Setting (ampere)	Ozone Production (lb/day)	Power Consumption Generator (kW)	Power Consumption Support Systems (kW)	Total (kW)	Power Utilization (kWh/lb)
40	17.1	4.6	13.1	17.7	24.8
50	22.9	6.4	13.1	19.5	20.4
60	----	---	----	----	----
70	32.5	9.9	13.1	23.0	17.0
80	36.2	11.4	13.1	24.5	16.2
90	40.0	13.1	13.1	26.2	15.7
100	43.9	15.1	13.1	28.2	15.4
110	47.2	17.2	13.1	30.3	15.4
120	50.3	18.8	13.1	31.9	15.2
130	53.9	20.8	13.1	33.9	15.1
140	56.8	22.6	13.1	35.7	15.1
150	----	----	----	----	----

lb day x 0.454 = kg/day; kWh/lb x 2.21 = kWh/kg

*Air Compressor = 8.35 kW, Refrigerant Drier = 1.20 kW, Air Drying Tower Heater = 1.48 kW and Generator Cooling Water = 2.10 kW.

less efficient electrical energy usage occurs at lower ozone production requirements. The fact that the power utilization increases dramatically at low production requirements has significant impact when applied to wastewater treatment plant operation.

At the UTSD plant, variations in wastewater volume and effluent quality occur. Although flow equalization is available, plant flows have ranged from 1140 cu m day (0.3 mgd) to 3,780 cu m/day (1.0 mgd). To optimize ozone dosages in line with these flow variations, an adjustable ozone generation system is required. The present system at the UTSD facility is adjustable by varying the amperage setting but at low ozone production operating requirements, the system operates in the least efficient electrical energy usage range.

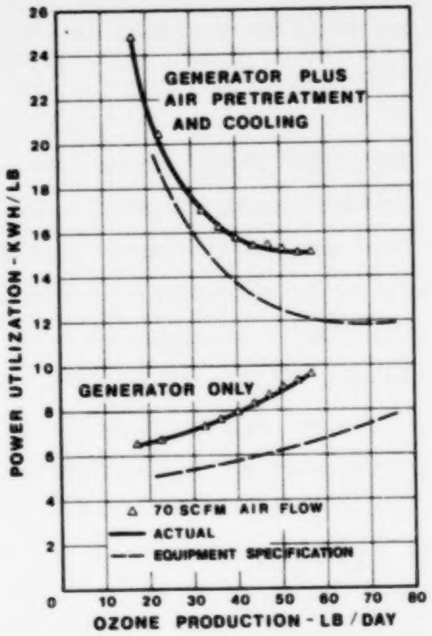


Figure 28. Comparison of equipment specifications and actual UTSD ozone generation system power utilization (scfm x 1.70 = cu m/hr); lb/day x 0.0189 = cu m/hr; kWh/lb x 2.21 = kWh/kg.

Similarly, municipal wastewater treatment plants are typically designed for future and larger flow rates. Also, most of these facilities are designed without flow equalization capabilities. As such, lower ozone production requirements will most likely occur during the design life and even during diurnal periods. At a lower ozone production requirement, the power utilization value could be much greater than at design production levels which would result in operation of a proportionately less economical ozone disinfection system than would occur at design flows. The need for economical ozone production over an adjustable range exists. In order to have this flexibility a more uniform power usage efficiency must be developed. Multiple ozone generation and/or multiple air pretreatment units should be considered in order to achieve more uniform power utilization values for a broad range of ozone production requirements that can be expected to occur with municipal wastewater treatment facilities.

The UTSD ozone system was intermittently operated because of periodic high ambient ozone concentrations in the plant working environment. Several modifications to the ozone piping and contact basin were made to reduce the ambient ozone concentration when the generators were operated. One remaining modification is an ozone destruct unit for the off-gases from the ozone contact basin. This unit has been designed and is being constructed, and represents another source of power consumption associated with the ozone system. The expected power consumption is between 8 and 17 kW.

March 1979 Update--

During the data collection phase of the research project the dew point of the air from the USTD ozone generator air pretreatment system was measured with a Shaw Model "S" Mini Hygrometer which had a red spot probe. This data indicated that the air pretreatment system worked well in that the dew point of the air varied from -74°C to -54°C, where -51°C was the dew point recommended by the manufacturer. However, subsequent to the data collection phase of the research effort, new information was recieved that indicated that the Shaw dew point meter may be giving inaccurate readings(6). Subsequently, the ozone manufacturer was contacted regarding this item and consented to sending a dew point cup measuring device to the UTSD plant for purposes of measuring the dew point of the air from the air pretreatment system. The dew point cup was received and comparative dew point readings were taken in March, 1979.

A diagram of the dew point cup measurement device is illustrated in Figure 29. As shown, the air stream is directed onto the side of a polished stainless steel cup that is attached to an outer container. About 2.5 to 5 cm (1 to 2 inches) of acetone is placed into the cup and ice is slowly added to the acetone until water in the "dry air" stream condences on the polished stainless steel. A thermometer that had been placed into the acetone/dry icer mixture is then read, and the temperature reading at that instance is the dew point reading of the air stream. Using this procedure reproducible results were obtained and were considered to be quite accurate measurements of the air dew point. (Note: A minimum amount of tygon tubing is used to pipe the air flow to the dew point cup to avoid possible moisture uptake in the tygon tubing.)

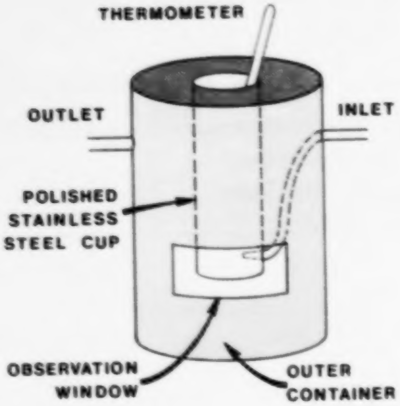


Figure 29. Schematic Diagram of dew point cup air dew point measuring device.

The dew point results using the dew point cup were found to be significantly higher than the results using the Shaw Mini Hygrometer, as shown in Table 35. The dew point cup results ranged 42°C, from -53°C to -11°C, while the Shaw meter readings ranged only -6°C, from -74°C to -68°C. The Shaw meter definitely was not as sensitive as the dew point cup. More importantly however, the Shaw meter results indicated that dew point levels for the air pretreatment system were better than minimum acceptable levels of -51°C specified by the ozone manufacturer. Conversely, the dew point cup results indicated that the dew point was usually higher than the desired minimum value of -51°C.

Based on this new information of the actual dew point of the air being greater than specified by the ozone manufacturer, different conclusions are indicated for some of the information presented in the text of this report. Some conclusions remain essentially unchanged and still other new conclusions are dictated. The remaining discussion is presented with respect to the new and more accurate dew point information.

Generator Flooding-- As discussed, several occasions of generator flooding occurred. In order for this condition to occur, the air drying towers must be saturated condition, the desiccant material in the towers loses effectiveness as a drying agent. It is suspected that the desiccant in the UTSD drying tower is ineffective. New desiccant material has been ordered.

TABLE 35. COMPARATIVE DEW POINT READINGS OF DEW POINT CUP VERSUS SHAW MINI HYGROMETER, MARCH 15, 1979

Drying Tower Operating Time (hr)	Air Dew Point Dew Point Cup (°C)	Air Dew Point Shaw Mini Hygrometer (°C)	Ozone* Concentration (ppm/vol)
0	-42	-72	2683
1	-53	-74	2756
2	-41	-74	2648
3	-34	-72	2621
4	-26	-72	2502
5	-19	-70	2368
6	-15	-69	2314
7	-12	-68	2195
8	-11	-68	2170

*Ozone concentration using Dasibi Meter. Generator air flow was 118 cu m/hr (70 scfm).

The generator flooding problem was associated with four major items; 1) continuous overloading of the air drying towers, 2) sticking of the linkage in the tower switching mechanism, 3) refrigerant drier failure and, 4) low water flow to the water ring compressor due to plugging of an in-line filter that could not be detected due to improper placement of an in-line pressure gauge. The cause of the refrigerant drier failure was unknown. It is now suspected that the failure was due to an extreme high temperature oveloading problem caused by item number 4 above. Of all the above mentioned items, item number 2 was most directly related to operational considerations. The other items were related to the design arrangement of the ozone system purchased as a package unit from the manufacturer. These items have now been corrected by installing an air flow valve after the air compressor and before the refrigerant drier and air drying towers, and by placing the pressure gauge used to indicate the pressure of the water to the water ring compressor at a point after the inline filter screen.

Dew Point Monitoring-- A conclusion was reached that a method of monitoring the dew point and sounding an alarm for a high dew point level was necessary. This conclusion is now more valid than ever. In addition to preventing generator flooding, it would also have reduced the rate of desiccant failure that apparently has occurred at the UTSD plant. However, in view of the poor accuracy of the Shaw dew point meter, an expanded aspect of the conclusion that a dew point meter and alarm should be provided, is that a dew point cup measuring device should also be provided in order to properly calibrate the dew point meter and/or properly set the dew point high level alarm.

Generator Production Verses Dew Point--The Shaw dew point meter indicated that the air dew point was always better than the manufacturer's minimum acceptable level of -51°C. The later obtained dew point cup results indicated that the opposite was true, and thus the air pretreatment system was not functioning satisfactorily. The ozone production results did change when the Shaw meter indicated a change in dew point, but the actual dew point values were probably higher than the minimum acceptable levels. A quantitative figure of the actual dew point values was not obtained, but values of 30 to 40°C higher than minimum acceptable levels may have occurred. The conclusion that ozone production changes as dew point chnages is still valid, but for a different range of dew point values than indicated previously. It should be noted that, according to the ozone equipment manufacturer, ozone production does not change appreciably when the actual dew point is lower that -51°C. This could not be verified at the UTSD plant, but hopefully will be when the new desiccant material is installed.

The conclusion that ozone dosage will vary during a drying tower cycle along with the recommendation that accompanied it, was extremely critical for the actual air dew point levels experienced. They are less critical if generator production does indeed change only slightly during a typical drying tower cycle, when the actual dew point level is always lower than 051°C. However, the concept of the conclusion and associated recommendation still is valid, and it is still felt tha much benefit would be derived if ozone generator manufacturers would provide specific, or at least a range of generator production values for various power settings and dew point levels for their particular systems. This information would greatly aid design engineers in system design, and also would be extremely beneficial to plant operators since they would be able to periodically check their system's performance with expected values. In so doing, minor problems may be corrected if the system performance was noted to be poorer than expected, and corrective action initiated which may prevent major and more costly problems from occurring.

The maximum ozone production level of the UTSD generator was 1.26 kg/day (57 lb/day); which was 25% less than rated by the manufacturer. The major reason for the lower ozone production level is now attributed to a low actual dew point of the air fed to the generator. It is not known if the generator will meet or exceed production specifications when the drying tower desiccant is replaced and the dew point is lowered, but certainly much better performance is expected.

Generator Power Requirements Verses Dew Point--The actual power utilization values obtained during the research project were greater than expected design values, because the ozone production rate was lower than expected. It is now felt that the major reason for the low producton levels was due to a higher than minimum acceptable dew point of the air feed stream. When the dew point decreases, the level of ozone production is expected to increase and the relative power utilization values decrease. However, this aspect was considered in the discussion of ozone system power requirements. Therefore, no changes in the overall conclusion regarding ozone power requirements as discussed are necessary.

Ozone Contacting System--

Ozone produced in the generators was directed to the ozone contact basin. Several design modifications were made to the ozone contact basin and ozone piping arrangement. Some of the modifications represent "state of the art" design changes that evolved over the 2-year operation period of the UTSD ozone system. The modifications made include: contact basin covering, basin exhaust changes, baffle and scum skimmer changes, and ozone piping and diffuser replacement and an ozone destruct system.

An initial obstacle in operating the ozone disinfection system was the presence of high ambient ozone concentrations in the operator working environment. Present minimum acceptable standards for human exposure to ozone are 0.1 ppm by volume for a period not to exceed 8 hours. During initial start-up, ambient ozone concentrations of 3-5 ppm by volume for 2-hour periods, with peaks of 15-30 ppm by volume were encountered.

It was determined that a portion of these high ambient ozone concentrations were the result of a partially covered contact basin. Additionally, the part of the tank which was covered was not sealed. The contact basin was modified by covering the entire basin with aluminum plates and sealing the joints with hypolon gasket material. It was anticipated that a covered and sealed basin would prevent off-gas leaks.

When the revisions were completed, ozonation was again attempted but high ambient ozone concentrations still occurred. This problem was isolated to ineffective sealing of the basin cover. A silicone caulk was applied in a continuous bead to obtain a positive seal. High ambient ozone concentrations above the contact basin were reduced, but were then detected in the main plant offices. Off-gas that could no longer escape through the basin cover was being forced to the air space above the backwash water storage basin. This basin was adjacent to the ozone contact basin and below the main plant offices. Additionally, contact basin off-gases were not being properly vented to the roof discharge because foam produced by the addition of air and ozone to the contact basin was blocking the exhaust air flow to the vent duct.

To correct the problem of off-gas leakage from the backwash storage basin, a duct connecting the existing ozone contact basin with the air space above the backwash storage tank was installed. The addition of the duct eliminated high ambient ozone concentrations in the plant offices, because when foam blocked the movement of air above the water surface of the ozone contact basin the ozone laden off-gases would transfer to the backwash water storage basin where they would be pulled back into the main exhaust duct and discharged. This duct provided an alternate means for ozone laden air to be removed when foaming occurred. In addition to the duct modification, a water spray nozzle was installed in the ozone contact basin duct to depress the foam as it developed. It should be noted that the excessive foaming problem occurred during ozone system start-up and typically lasted for only 2-3 hours.

During initial operation of the ozone contact system it was determined that short-circuiting of flow was occurring across the top of the compartment baffles. This short-circuiting resulted when air/ozone from the diffusers "air-lifted" the water level in the basin. The baffles were raised slightly, but not to the extent that air movement to the exhaust vent was blocked.

The air-lift action caused by the diffuser system also caused flooding of the scum skimmer mechanisms which were initially set too low. The adjustment range of the skimmer units was expanded and adjustment handles were extended through the basin cover. To facilitate adjustment of the overflow weir plates, plexiglass sight windows were installed into the basin cover above each skimming unit. To date, the continuous use of the scum skimmers has been unnecessary as little foam or the predicted gelatinous type froth has been produced. The lack of appreciable foam or froth is believed to be due to the high quality water entering the ozone contact basin. This water has very little material (i.e., total suspended solids) available to be coagulated into froth.

The combination of modifications allowed operation of the ozone system whenever the wind was blowing sufficiently to remove the ozone laden off-gases from the area surrounding the discharge stack. The system had to be shut down when the wind was not blowing because high ambient ozone concentrations would develop in and around the plant area. The UTSD was instructed by State Department of Health officials to operate the ozone system to achieve disinfection, but the District was allowed to shut down the system when necessary to prevent human exposure to high ambient concentrations of ozone. Under this arrangement, it is estimated that the ozone disinfection system was operated only about 50 percent of the time.

The UTSD ozone system was operated under these conditions for about one year when problems were encountered with the ozone diffusers and with leaks in the ozone piping. The original ozone piping from the generator to the ozone diffusers was Schedule 80, U.P.V.C. pipe with both solvent weld and threaded joints. The problems with leakage occurred around the joints and along straight pipe sections near pipe hangers. This leakage problem may have been caused by inadequate care during installation; however, good plumbing practices by the contractor were felt to exist because very few problems occurred with other plant piping systems. Although no definite conclusions could be developed, the leakage in the ozone piping may have occurred as a result of ozone exposure over a one-year time period and not due to poor workmanship.

Because of the excessive ozone leakage of the U.P.V.C. pipe, all piping was replaced with Schedule 40, Type 304 stainless steel. Some of the stainless steel pipe connections were threaded and some were welded. Some of the threaded stainless steel connections were noted to leak and were tightened, but some could not be sealed and were eventually welded. It was concluded that welded connections provided the best assurance for sealing.

When U.P.V.C. piping was replaced new ozone diffusers were also installed. The diffusers were connected to the stainless steel pipe outside the basin, and the pipe with diffusers was lowered into the basin aided by the structural integrity of the stainless steel pipe. During installation of the diffusers an additional reason for replacing the U.P.V.C. piping with stainless steel pipe was noted. Upon removal of the U.P.V.C. pipe that had been submerged in the contact basin it was noted that the pipe was extremely brittle and shattered easily when dropped. The U.P.V.C. pipe's condition was not felt to be acceptable for long-term operation, and replacement with stainless steel pipe was considered appropriate. These results indicate that strong consideration should be given to using suitable grade stainless steel pipe and welded connections for all ozone/air piping.

The UTSD Ozone contact basin achieved ozone transfer efficiencies ranging from 35 to 70 percent. Transfer efficiency (TE) as used in this context was calculated as follows:

$$TE = \frac{(\text{Mass of Ozone Produced} - \text{Mass of Ozone in Off-Gas})\ (100)}{\text{Mass of Ozone Produced}}$$

Typically, the transfer efficiencies were between 50 and 60 percent, which were considerably less than the design TE of 90 percent. One reason for the lower than expected TE was breakdown of the ozone diffusers. The original ozone diffusers were tubuler in shape and were attached to a piping connection nipple with a "2-part epoxy bond". The epoxy served in a structural as well as a gas sealing capacity. Because the measured transfer efficiencies were lower than expected, the contact basin was drawn down and the diffusers were inspected. It was noted that the epoxy had become extremely soft. The diffuser manufacturer claimed that the epoxy would probably become "a little soft" when exposed to water. A new diffuser was exposed to water for 3 months in the laboratory. No softening effect was noted. During this time the TE had reduced from 50 to 60 percent to only about 35 percent. The contact basin was again drained and this time some diffusers were noted to have completely separated from the connection nipple and had fallen to the bottom of the contact basin.

The original ozone diffusers were replaced. The new ozone diffusers were porous stone and were also tubular in shape, but a bolted stainless steel connection and hypolon gasket material were incorporated in the diffuser construction. This construction eliminates the need for the two part epoxy bond which was not ozone resistant. Operation with the new diffusers has been limited and final conclusions concerning the suitability of the diffusers has not been reached.

After installation of the new ozone diffusers and stainless steel piping, TE tests were conducted and were found to be similar to efficiencies that were attained when the ozone system was first started up, namely 50 to 60 percent. These values were better than the 35 percent efficiency attained when some of the original diffusers were known to have failed, but were still less than the design efficiency of 90 percent. A re-evaluation of the ozone contact basin design was made.

The UTSD ozone contact basin design was similar to a basin that was designed and tested in 1971 at the Louisville, Kentucky Wastewater Treatment Plant. The ozone basin at Louisville was reported to have consistantly achieved 90% or greater TE. At about that same time at the University of Louisville, research work was conducted to measure the TE of a contact basin similar to the basin that was tested at the Louisville plant, and a paper was published concerning the results. The author reported that the 90% to 95% TE that was achieved at the Louisville plant could not be duplicated at the University laboratory. Laboratory results indicated a TE of about 50%. The difference in transfer efficiency was attributed to a "with reaction" consumptive use of the applied ozone at the Louisville plant, which was ozonating secondary effluent. The phrase "with reaction" implies that the effluent being treated had a high ozone demand and that available ozone was consumed by this demand. Thus TE appeared much higher because of this ozone demand. The tests completed at the University of Louisville, which did not correlate with Louisville plant results, were labeled "without reaction" test results. These "without reaction" tests also correlated well with ozone/liquid gas transfer theories.

Transfer efficiencies achieved at the UTSD facility have also correlated well with ozone/liquid gas transfer theories, and are believed to be more in line with the "without reaction" tests conducted at the University of Louisville. The wastewater ozonated at the UTSD plant is tertiary effluent and of considerably better quality than typically associated with secondary treatment.

The belief that the UTSD ozone contact basin was performing similarly to the "without reaction" tests as established at the University of Louisville was further supported. Periodically, the ozone transfer efficiency has reached a level of about 70 percent. When this occurred, poor disinfection results were often achieved even if disinfection previously occurred at similar ozone dosages. At the same time, the TSS concentration through the basin increased. This condition existed when the ozone generator was started after being shut down for a day or two. The air pretreatment system was always operated, thus air was continuously diffused into the wastewater. When the ozone generator was shut off or was operated at a very low ozone dosage level, biological growth developed in the basin in the form of a slime on the basin walls, the U.P.V.C. baffles, and other surface media in the basin. When the ozone generator was started and operated at a higher ozone dosage, a "with reaction" ozone consumption probably occurred and increased the ozone transfer efficiency to near 70%. At the same time, the biological slime would slough-off and increase the contact basin effluent TSS concentration which interfered with the disinfection capability of the system. However, when the UTSD ozone contact basin is operated on a continuous basis it is expected that it will operate according to gas/liquid transfer theories. It was concluded that the basin is achieving expected ozone transfer efficiency for the quality of effluent treated. Based on these developments, design considerations for desired ozone contact basin transfer efficiencies should be based on ozone/liquid gas transfer theories.

Biological slime build-up occurs in the UTSD ozone contact basin when the ozone generator is shut down and/or operated at a very low ozone dosage level. Because of this problem with intermittent ozone operation, a good disinfection versus ozone dosage relationship was not obtained. When continuous ozonation and continuous good disinfection is achieved, the ozone dosage will be adjusted to determine the minimum level necessary to achieve disinfection. Transfer efficiency tests will be made to determine the effective ozone dosage as opposed to applied ozone dosages (i.e., dosage excluding the ozone lost in the off-gas) so that a common basis of comparison can be made with other ozone disinfection systems.

To achieve continuous ozonation, several options were considered to control the off-gas ozone discharge. Among these were: heat destruct, heat/catalyst destruct, activated carbon, recycle to sludge, and discharge through a tall stack. The option selected was heat/catalyst destruct. Heat destruct was rejected because of an excessively high power consumption. Activated carbon was rejected because of its explosive potential when combined with ozone. Recycle to sludge and discharge through a tall stack were rejected because they were felt to likely result in transferring the problem to another area within the plant. The heat/catalyst ozone destruct system for the contact basin off-gases has been designed and is being constructed. The system is manufactured by Emery Industries. An off-gas ozone destruct unit should be strongly considered for all newly designed ozone systems.

In March, 1979, the off-gas destruct unit was installed and operated for only a short period of time, because a 0.39 kW (1/2 hp) fan motor used to draw the off-gas through the destruct unit burned out. The smaller motor is being replaced with a 0.75 kW (1 hp) motor. Preliminary indications are that the off-gas ozone destruct unit satisfactorily reduced the ozone concentration in the off-gas to satisfactoy levels to allow continuous operation of the ozone system. Quantitative information was not obtained, but from a qualitative stand-point the system was acceptable.

Disinfection Performance--

Operation of the ozone disinfection system at the UTSD plant was sporatic due to a variety of problems that resulted in high ambient ozone concentrations representing a hazard to operating personnel. Shown below is a synopsis of the problems encountered.

Time Period	Comment
June - December, 1976	High ambient ozone concentrations due to partial cover over contact basin.
December, 1976 - February, 1977	Good disinfection achieved, but equipment to measure ozone dosages and transfer efficiencies not available.
March - April, 1977	Good disinfection achieved.
May - June, 1977	Poor disinfection achieved because of ozone diffuser problem.
July - October, 1977	System shut down for inspection and repair of original ozone diffusers.
October - December, 1977	Relatively good disinfection, but only with extremely high ozone dosages because of further problems with ozone diffusers.
January - April, 1978	Design, construction and installation of new ozone diffusers completed.
May - September, 1978	Sporatic operation due to excessively high ambient ozone levels in and around the plant area due to high ozone concentrations in contact basin exhaust. Plans and specifications for off-gas ozone destruct system developed.

Routine collection of analytical data for the ozone system was initiated during the week of December 12, 1976. Results from these analyses for the entire research period are shown in Appendix F. The majority of the results shown are weekly arithmetic averages of data collected based on the analytical schedule that was presented in Table 13. Coliform results shown in Appendix F are weekly geometric means of the individual coliform determinations. Coliform data was developed using the membrane filter (Gelman Filter) technique through the week of April 10, 1977. Results after April 10, 1977 were developed using the Most Probable Number (MPN) technique.

In general, good disinfection performance could be achieved when the ozone diffusers were in good condition and the system was operated for an extended period of time (several days). Disinfection performance was poor when problems were occurring with diffusers and when the ozone system was operated on an intermittent basis. A summary of performance data for selected time periods is shown in Table 36. Periods 1, 2 and 3 represent data collected when the original ozone diffuses were in operation. Period 4 represents data collected after the new diffusers were installed.

During the 8-week time period for Period 1, the original ozone diffusers were new and were operating satisfactorily. Very good disinfection occurred at an average applied ozone dosage of about 11 mg/l. The effluent fecal coliform concentration was reduced to 30 per 100 ml, much better than the design standard of 200 per 100 ml. The COD reduction during Period 1 was 12 percent and the TSS reduction was 36 percent. Both the influent COD and TSS concentrations were relatively low at 30 mg/l and 5 mg/l, respectively.

During Period 2 the average applied ozone dosage was about 9 mg/l, but disinfection performance deteriorated significantly. The effluent fecal coliform concentration was 2,080 per 100 ml. The reason for the poor performance was primarily attributed to problems with the ozone diffusers. During Period 3 disinfection improved, but only after the applied dosage was more than doubled to about 19 mg/l.

The performance data for Period 4 represents information collected after the new ozone diffusers were installed. The data was collected for two different time periods because of problems with intermittent ozone generation and

OZONE DISINFECTION

TABLE 36. SUMMARY OF PERFORMANCE DATA FOR SELECTED TIME PERIODS

Period	Date	No. of Wks.	Applied Ozone Dosage*	Total Coliform		Fecal Coliform		COD in Effluent & Reduction***		TSS in Effluent & Reduction	
				Inf	Eff	Inf	Eff				
			(mg/l)	(#/100 ml)	(#/100 ml)	(#/100 ml)	(#/100 ml)	(mg/l)	(%)	(mg/l)	(%)
1	2/27/77 To 4/23/77	8	11*	210,000	167	38,000	30	26	12	3	36
2	4/23/77 To 6/18/77	8	9**	340,000	25,000	14,600	2,080	40	7	6	22
3	10/16/77 To 12/10/77	8	19**	11,400	-	1,250	91	43	8	8	9
4	4/16/78 To 4/29/78 Plus 5/21/78 To 6/3/78	4	7*	11,300	31	4,455	9	36	10	3	3

*During these time periods the system achieved a maximum of 50 to 60 percent ozone transfer efficiency.

**During these time periods the system achieved a maximum of about 35 percent ozone transfer efficiency.

***Reduction is process efficiency across the contact tank.

biological slime build-up. Effluent disinfection was achieved during Period 4. The effluent fecal coliform concentration was only 9 per 100 ml at an applied ozone dosage of about 7 mg/l.

These performance data are limited, but indicate that good disinfection can be achieved with the UTSD ozone system. More definitive conclusions are expected when the ozone destruct unit for the contact basin off-gas is operational and continuous ozonation can be implemented.

SLUDGE DEWATERING AND DISPOSAL

Sludge dewatering facilities are provided at the Upper Thompson Plant to condition the sludge from the aerobic digesters for land disposal. Process operation is discussed in this section. Areas investigated included the digested sludge characteristics, design features, and initial performance data. Results were collected during an initial start-up period and then through a 60-day testing period.

Start up of the Upper Thompson Plant began in April, 1976; however, operation of the sludge concentrator did not begin until nearly two years later in February, 1978. This delayed operation was caused by delays in finalizing the design and construction of portions of the sludge handling system. Throughout this two year period the waste sludge from the activated sludge system was accumulated in the two aerobic digesters. This long detention time resulted in a very well digested sludge, as indicated by a specific oxygen uptake rate of less than 0.5 mg/hr/gm VSS and the volatile solids to total solids ratio of less than 60 percent. An additional factor that affected the digester sludge occurred during the Big Thompson flood disaster (July 31, 1976). A 76 cm (30-inch) main interceptor river crossing was washed out and resulted in a large amount of silt-laden water entering the activated sludge system. Consequently, the contents of the activated sludge process were wasted to the aerobic digesters. The silt material coupled with the long sludge detention time resulted in a large mass of inert material contained in the aerobic digesters.

Because of the unusual characteristics of the sludge to be dewatered, several tests were required to select the most suitable polymer. A six place paddle mixer was used to perform standard jar tests on the digested sludge. Several types of polymer were investigated, and once a specific polymer was chosen several dosages were investigated to determine the optimum concentration. The polymer used through most of the study was Nalco 627.

During start-up of the sludge concentrator, a major limitation with the sludge feed system to the concentrator was detected. Because of head conditions, the sludge feed pump could not maintain the flow rate to the concentrator at a constant level. With a varying sludge flow rate the desired polymer dosage was difficult to maintain. As a result the characteristics of the conditioned sludge varied which directly affected concentrator performance. With the original arrangement, a diaphragm pump was located in-line between the aerobic digesters and the sludge concentrator. However, the liquid level in the digester was higher than the concentrator which created a positive head on the sludge pump. Sludge would flow by gravity through the diaphragm pump, limiting the pumps capability to control the sludge flow rate. As a result, a modification was necessary. As a temporary solution, a 1140 l (300-gal) tank was placed inside the sludge handling building and sludge from the digesters was allowed to flow by gravity to the tank where it was then pumped to the concentrator. This method of operation required the attention of an operator to direct sludge into the 1,140 ml(300-gal) tank, but it did insure a constant sludge flow to the concentrator. As a more permanent solution, a progressive cavity pump was installed in place of the diaphragm pump (March 1979).

The results of initial testing on the sludge concentrator are shown in Table 37. The testing was conducted in May, 1978, after the sludge feed system had been modified to provide a constant feed rate. Although no quality tests on the digested sludge were performed for trial 2, the characteristics should have been similar to those shown in trial 1 since the digester contents had been maintained for such a long time period. During the two testing periods the solids concentration of the sludge cake was 9.1 and 9.6 percent by weight. Solids capture varied from 78 to 82 percent, whereas captures greater than 90 percent were expected. The reason for the low solids capture was partially attributed to the extremely digested condition of the sludge being dewatered. It is noted that the digester contents had a very low pH (4.2 units). Sodium bicarbonate was added on several occasions to attempt to increase the pH but bench scale tests indicated that much more biocarbonate would be required to effect the pH. It was decided to dewater the sludge already contained in the digester and to attempt to control the characteristics of any future sludge through operational controls.

The average of the results for the two trials shown in Table 37 indicate that approximately 110 Kg (245 lb) of sludge (dry wt) were fed to the concentrator

TABLE 37. SLUDGE CONCENTRATOR PERFORMANCE DURING START UP

	Trial 1	Trial 2
Date	March 3, 1978	March 4, 1978
Duration - hours	4.9	3.8
Sludge Characteristics		
Total Solids - mg/1	32,560	---
Total Voltile Solids - mg/1	17,760	---
VS/TS Ratio - %	55	---
Temperature - °C	29	---
Specific Oxygen Uptake Rate mg O_2/hr/gm VS	0.13	---
pH - units	4.2	---
Performance		
Influent Flow Rate - gpm	15	15
Total Solids, Cake - %	9.1	9.6
Suspended Solids, Filtrate - mg/1	4,480	2,770
Sludge Feed Rate - lb/hr (dry wt.)	245	245
Sludge Cake Produced - lb/hr (dry wt.)	190	200
Sludge Lost in Filtrate - lb/hr (dry wt.)	55	45
Solids Capture - %	78	82
Polyer Dosage - lb/ton sludge (dry wt.)	39	41

gpm x 0.0631 = 1/sec; lb/hr x 0.454 = kg/hr; lb/ton x 0.50 = kg/metric ton per hour, and with a solids capture of 80 percent, 90 Kg/hr (200 lb) of sludge cake (dry wt) was produced at a polymer dosage of 20 Kg/metric ton (40 lb/ton) of sludge. It is noted that the speed of the primary and secondary screens had to be carefully controlled to avoid solids loss over the screen edge during these trials.

Subsequent to these initial tests, operation and performance data on the sludge concentrator was collected over a 60-day testing period from August 1 to October 1, 1978. A summary of this data is shown in Table 38. Overall performance during this period was better than that obtained during the initial testing period in May. Additional operations experience was felt to have contributed to the improved performance. During the 60-day period, sludge with an 11 percent solids content was produced which yielded 18,900 kg (41,700 lb) of dry sludge solids. To condition the sludge, 25 kg (50 lb) of polymer per ton of dry solids was required. On the average it required 8.3 hours to produce one metric ton of dry sludge solids.

TABLE 38. SUMMARY OF OPERATION AND PERFORMANCE DATA

Date	August 1, 1978 to October 1, 1978
Duration - hr	192
Sludge Characteristics	
Total Solids - mg/l	25,400
Total Volatile Soilds - mg/l	14,660
VS/TS Ratio - %	58
Temperature - °C	No Data
Specific Oxygen Uptake Rate - mg O_2/hr/gm VS	No Data
pH - units	5.5
Performance	
Influent Flow Rate	20
Total Solids, Cake - %	11
Suspended Solids, Filtrate - mg/l	2,070
Sludge Feed Rate - lb/hr (dry wt.)	254
Sludge Cake Produced - lb/hr (dry wt.)	217
Sludge Lost in Filtrate - lb/hr (dry wt.)	37
Solids Capture - %	85
Polymer Dosage - lb/ton sludge (dry wt.)	50

gpm x 0.0631 = l/sec; lb/hr x 0.454 = kg/hr; lb/ton x 0.50 = kg/metric/ton

During the 60-day testing period, an operation problem was encountered with the inlet and outlet flapper valves on the sludge feed pump. These valves collected pieces of rags and bits of plastic from the sludge. The valves would then not seat properly and the flow would slowly decrease. To minimize this problem, the output of the pump was checked once or twice per hour, and adjusted to maintain a 75 l/min (20 gpm) flow. During the 60-day test period the pump was taken apart five times to remove the rag and plastic build-up on the valve seats. Approximately 30 min of cleaning time was required each time the pump was taken apart.

Additional operational problems had to do with maintaining a good sludge floc. It was determined that when sodium bicarbonate was added and the digester sludge pH increased to greater than 7, the cationic polymer that had been used had little effect on flocculating the sludge. Flocculation problems also occurred when attempts to dewater sludge from one of the digesters that had not had any waste activated sludge added to it for 3 weeks were made. This sludge produced such a poor floc that the primary screen of the concentrator could not trap the floc particles. When sludge was processed from the other digester that had waste activated sludge fed to it daily, a good floc was again achieved.

The spray jets used to clean the primary and secondary screens also provided some operational difficulties. Plant effluent was used to supply water to the 1.2-mm (3/64 inch) jets, and small particles clogged the jets. The semi-plugged spray jets would not adequately clean the screens. To minimize the plugging problems, the jets were cleaned before each 6 hour filter run. An inline strainer is being investigated to aid in trapping these small particles before they entered the spray jet. The strainer should not have to be cleaned as often, and more importantly the effectiveness of the spray jets would be maintained.

During operation of the sludge concentrator, water and solids (filtrate) were returned to the plant headworks. The added water is from the water released from the sludge, the water added by the inline polymer diluter, and water added by the jet cleaning sprays. The water released from the sludge was about 57 l/min (15 gpm), the water added by the inline polymer diluter about 30 l/min (8 gpm) and the water required to operate the spray jets about 57 l/min (15 gpm) for a total volume of about 144 l/min (38 gpm). Solids in the filtrate result from the sludge lost through or over the edge of the travelling screens. The filtrate total suspended solids concentration during the test period averaged 2,070 mg/l. The amount of solids in the filtrate varied directly to the dryness of the sludge. The highest solids content of the filtrate, 4,740 mg/l, occurred with a poorer sludge cake of 9.4 percent while the lowest solids of 344 mg/l occurred with a good sludge cake of 12.1 percent.

A cost breakdown for the 60-day testing period is shown in Table 39. A total of 114 man hours was required for operation of the sludge concentrator. This labor included time for start up, operation, maintenance and clean up. Electrical power to operate the sludge dewatering system was estimated to be 176 kW/metric ton (88 kW/ton) of dry sludge solids. The cost was obtained by multiplying the total kilowatt consumption by the UTSD power cost factor of $0.035/kW. Sludge cake transportation included allowances for gasoline and the drivers' time, but insurance and depreciation on the truck were not included.

TABLE 39. SUMMARY OF COST DATA FOR SLUDGE DEWATERING

Labor	Polymer	Power Costs	Hauling
114 man hrs.	1060 lbs x	1830 kW x	$60.00 labor (@ .58 hrs/ton)
x $5.00/hr =	$1.221/lb =	$0.035/kW =	15.92 gas (@ $0.65/gal)
$570	$1,294	$64	$75.92 Total

Cost Per Ton Dry Sludge Removed

Labor: $570 ÷ 20.8 tons = $27.40
Polymer: $1,294 ÷ 20.8 tons = 62.22
Power - $64.06 - 20.8 tons = 3.08
Hauling & Labor: $60.00 ÷ 20.8 tons = 2.88
Hauling & Gasoline: $15.92 ÷ 20.8 tons = .76
TOTAL $96.34/Ton Dry Sludge

lb x 0.454 = kg; hr/ton x 0.907 = hr/metric ton; gal x 3.785 = l; ton x 0.907 = metric ton

The total cost of sludge dewatering as shown in Table 39 was about \$87/metric ton (\$96/ton) dry sludge solids. The labor and polymer costs comprised 93 percent of the total cost.

The sludge concentrator was relatively easy to operate once the proper polymer dosage was determined. The full attention of an operator was not required and periodic checks were all that was necessary. Overall, the unit performed well despite the quite difficult-to-dewater aerobically digested sludge. It is expected that even better performance in terms of lower cost and a thicker sludge cake can occur, when a less inert sludge is processed.

OVERALL TREATMENT PLANT PERFORMANCE

The UTSD advanced wastewater treatment facility functioned under a variety of operating conditions throughout the data collection phase of the research project. Plant flows ranged from 30 percent to 134 percent of the design flow (Note: half plant design flow values were used because only half of the plants major units were in service). The BOD_5 load ranged from 50 percent to 228 percent of design. Despite these wide variations in loading, overall plant performance was quite good. A summary of the performance and the effluent quality for each unit process for the period of the research project is shown in Table 40. It should be noted that the effluent for each process was not sampled all the time during the data collection phase of the research effort. Initial plant lab start-up problems postponed individual unit process analyses for three months until October 3, 1976. Also, special testing for the ozone and denitrification systems was completed during the last two months of the data collection effort in place of sampling and analyzing every unit process. Thus, of 105 weeks of overall performance information, 88 weeks of data were collected on all individual unit processes. Data presented in Table 40 is for this 88-week period.

TABLE 40. SUMMARY OF UTSD PLANT PERFORMANCE*

Parameter	Influent	Activated Sludge Effluent	Nitrification System Effluent	Mixed Media Filter Effluent	Ozone Contact Effluent
Flow (mgd)	0.49	0.49	0.49	0.49	0.49
BOD_5 (mg/l)	201	31	34	11	11
Removal (%)	---	85	83	95	95
TSS (mg/l)	169	22	21	6	6
Removal (%)	---	87	88	96	96
COD (mg/l)	358	58	55	35	35
Removal (%)	---	84	85	90	90
TKN (mg/l)	22.5	11.6	8.6	6.8	6.4
Removal	---	48	62	70	72
NH_4-N (mg/l)	13.1	9.1	5.5	4.9	4.8
Removal	---	N/A	N/A	N/A	N/A
Alkalinity as $CaCO_3$ (mg/l)	106	76	49	45	45
Removal	---	28	54	58	58

mgd x 3785 = cu m/day

*Summary of data for 88 weeks from 10-3-76 to 6-10-78, excluding the 4-week period from 6-12-77 to 7-9-77 when modifications to the plant were completed.

Although each parameter could be discussed, it is felt that BOD_5 can be used to indicate the variations in organic loading and performance that occurred throughout the project period. The average influent BOD_5 concentrations shown in Table 40 was 201 mg/l, indicating a typical domestic waste. However, further data evaluation indicated that an extreme variation in waste strength occurred. The winter season wastewater BOD_5 concentration was only about 100 to 150 mg/l, and the summer BOD_5 concentration ranged from 250 to 400 mg/l. The BOD_5 removal efficiency ranged from 85 percent to 98 percent during the course of the study. A graphical illustration of BOD_5 removal efficiency is shown in Figure 30. The lower removal efficiency of 85 percent was attributed to system start-up conditions after plant modifications were made in June 1977.

Also shown in Figure 30 is the BOD_5 removal efficiency across the activated sludge system. As shown, activated sludge removal efficiencies were generally lower and more variable during the beginning portion of the project and more consistent and higher toward the end. More experienced process operation by plant personnel coupled with changes in system operation that were earlier discussed were contributing factors to this occurrence. It should be noted that lower overall plant BOD_5 removal occurred near the very end of the project even though activated sludge removal was quite good. The reason for this is due to higher BOD_5 in the mixed media filter effluent due to methanol addition during the denitrification special study.

Many minor and some major modifications have been implemented at the UTSD facility. These modifications coupled with the understanding of the loading conditions that are associated with the UTSD facility should allow continued good and even improved process performance. As such, the UTSD should be able to maintain a high quality effluent.

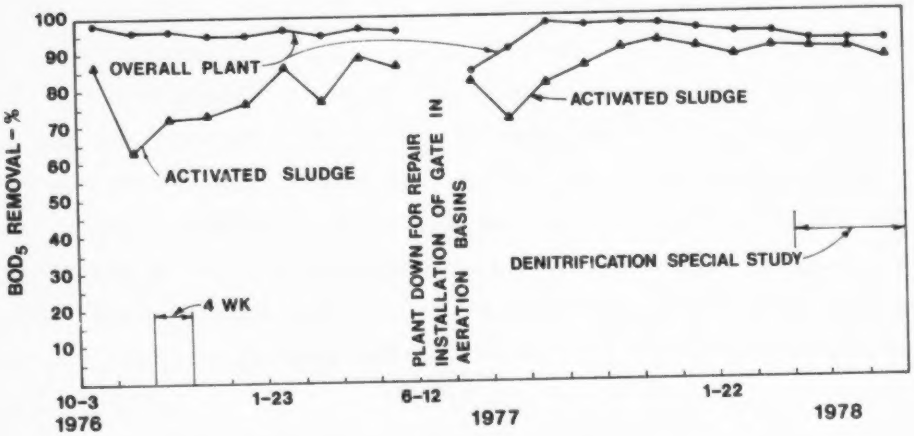


Figure 30. Activated sludge and overall plant BOD_5 removal efficiency during the entire research project.

OPERATION AND CAPITAL COST

The plant was constructed in 1975 and 1976, and the capital costs presented are associated with this period. Total capital cost for the UTSD treatment facility was approximately $3 million, or about $2 million per 3,785 cu m/day (1 mgd) of treatment capacity. This cost includes all subsequent modifications made in the plant design. Data on the operational cost of the plant were collected during the research project. The average annual operating cost during the research project was $152,210. Since the research project required additional manpower effort, this cost is not reflective of normal operation. The projected annual operating cost, excluding research project costs, was $123,000. In the following subsections the overall capital and operating costs are broken down for each of the specific unit processes. A summary of individual process costs, as well as total costs, is also presented.

Lift Stations

Two lift stations, Fish Creek and Big Thompson, were used to pump the collected wastewater to the treatment plant. The lift stations consisted of a wetwell, dry-well, pumps and a comminutor with bar screen by-pass. The total capital cost for both lift stations was $189,720. The cost for the pumps and comminutors comprised about $37,000 of this total. Construction materials and labor for the lift stations cost an additional $80,000. Piping, electrical systems, equipment controls, and site preparation at $72,720 accounted for the remainder of the total lift station cost. The capital cost of the lift stations was approximately 6.4 percent of the total plant cost.

Operational cost for the various treatment processes were divided into three categories: supplies, labor and power. Supplies for the lift stations consisted mostly of lubricants for the equipment. Since this cost was minor compared to the total cost, it has been included in the miscellaneous section of this analysis. Labor used for the inspection and maintenance of the lift stations was estimated to be 2.5 hours per day. The annual labor requirement was then computed as 912 man-hours, which was 10.2% of the total annual staffing cost and amounted to $5,016. The power requirement for the lift station was based on the horsepower of the operating pumps with respect to the total plant horsepower. This percentage, when used in conjunction with the average power cost for the plant of $3,766 per month, provided an estimate of the monthly power cost. The monthly power cost for the lift stations was $107, or $1,284 per year. When the labor and power costs were combined, the annual operation cost of the lift station was $6,300.

Flow Equalization and Grit Chamber

The capital cost of the flow equalization basin and grit removal units was $270,540, or approximately 9.1 percent of the total plant cost. Of this amount, $55,440 was the cost of the grit basin and related equipment, and the flow equalization basin and clarifier equipment. Materials and labor utilized in the construction of these facilities accounted for $116,730, and the remainder of the capital cost at $98,370 was the result of the associated piping, electrical systems, equipment controls and site preparation. It should be noted that site preparation for the UTSD was a significant cost, since much excavation work was done by blasting.

The cost of routine supplies for these units was negligible and was included in the miscellaneous section of this analysis. The labor cost associated with these units was based on 1.55 hours per day for inspection, grit handling and scheduled maintenance for a total labor requirement of 565 man-hours per year. The resulting labor cost was $3,108 per year. Based on the horsepower requirements, the preliminary treatment's share of the power cost was $211 per month, or $2,532 per year. When the power and labor costs are combined, the annual operation cost for preliminary treatment totaled $5,640.

Activated Sludge

The activated sludge system consisted of two aeration basins, two clarifiers, and the associated mechanical equipment. The estimated capital cost for the activated sludge system was $569,400, which accounted for about 19.2 percent of the total plant cost. Equipment cost including aerators, clarifier mechanisms, return and waste pumps and blowers was $119,680. Construction materials and labor accounted for an additional $243,055. Other capital costs at a total of $206,665 were for piping, electrical systems, equipment controls and site preparation.

The cost for supplies was considered negligible for this process and was included in the miscellaneous section. During the research project the manpower requirement for process control and sampling of this process was estimated to be 3,107 man- hours per year. The resulting cost for this effort was $17,090. A series of control tests were performed by the plant operators, and the frequency of this testing varied from four to six times per day. From 1 to 1-1/2 hours were necessary to complete a set of control tests. Additional time was required to develop and analyze the data and to implement the indicated process adjustments. Following the research project the frequency of performing the control tests and collecting samples for this process was reduced to twice per day, thus decreasing the manpower involvement to 1,969 man-hours per year and the annual labor cost to $10,830. The power cost for the activated sludge process system was based on the horsepower requirement of the blowers, turbines and pumps. The percentage of the power cost attributable to the activated sludge process was $1,126 per month. Total operational cost during the research project was $30,512 per year; however, following the project the annual cost decreased to $24,342 due to the decreased labor requirement.

Nitrification

Components of the nitrification system included the tower with two types of media - redwood and plastic, the recirculation pumps, and a wet-well.

The capital cost associated with the nitrification system was $366,760, or 12.4 percent of the total plant cost. Of this total, the tower structure, media and pumps accounted for $188,130. Materials and labor for construction of the system cost an additional $17,200. Other capital costs at $161,430 were allocated to the piping, electrical systems, equipment controls and site preparation.

The major operational costs for the nitrification system were based on labor and power requirements. An average of 0.34 man-hours per day were necessary for operation of the tower resulting in an annual labor cost of $682. Most of this time went to maintenance and inspection of the recirculation pumps. Only limited maintenance was required on the tower or distribution nozzles. The power cost, based on the horsepower of the recirculation pumps with respect to total plant horsepower, was estimated to be $552 per month, or $6,624 annually. The subtotal for operation cost of the nitrification tower was an estimated $7,306 per year.

Filtration

Major items within the filtration system include the mixed-media filters, backwash storage basin, backwash wastewater storage basin, pumps and the chemical feed system.

Approximately 12.8 percent of the total capital cost, or $378,510, was allocated to the filtration system. Cost of the filter units, backwash pumps and the chemical feed system accounted for $152,390. Materials and labor included in the construction of basins and the filter room were estimated to cost $74,200. The remainder of the capital cost at $154,880 went to the associated piping, electrical systems, equipment controls and site preparation.

Although a chemical feed system was included in the filter design, chemical addition was not practiced during the research project. The major operational costs were the result of manpower and power needs. The manpower required was mainly for filter backwashing. When the head loss through a filter reached a preselected level, an alarm was sounded. The operator then transferred the nitrification tower effluent to a clean filter, and initiated the approximately 15-minute backwash cycle on the dirty filter. The frequency of filter backwashing varied considerably during the research project, but the average backwash frequency was ten times per week. Manpower requirements of 1.25 man-hours per day were allocated for these activities. This resulted in an annual manpower cost of $2,508. The only power cost associated with the filtration system was the demand by the backwash pumps. This amounted to only $108 per year. Total operational cost, including labor and power, was $2,616 annually.

Ozone Disinfection

Components of the ozone system include the air pretreatment equipment, generators, contact basin and diffusers, and the off gas destruct unit. The capital cost of this system was $341,460, or 11.5 percent of the total plant cost. As discussed previously in the ozone evaluation section, several modifications were necessary in the system design, the most important being the piping and diffusers changes ($14,380) and the off gas destruct unit ($21,330) addition. The costs associated with these changes have been included within the capital cost. Approximately $160,300 of the capital cost was for equipment including: air pretreatment equipment, ozone generators, diffusers and piping, ozone monitoring equipment, and the off-gas destruct unit. Materials and labor utilized for construction amounted to $48,740. The cost for associated piping, electrical systems, equipment controls and site preparation was $132,420.

Operation of the ozone disinfection system required about $1,000 per year for materials. Most of this cost went to the purchase of electrode tubes and fuses. Manpower was required for daily inspection of the air pretreatment and ozone generation equipment. An additional 180 man-hours per year were necessary for inspection and cleaning the ozone generator units. These activities required an average of 1.2 man-hours per day, which resulted in an annual cost of $2,354. Determination of the power cost for ozone generation was difficult, since the unit was not continuously operated. Values obtained during intermittent operation were used to extrapolate the power costs shown. Costs shown are based on continuous operation. Since the off-gas destruct unit has been recently added to the system, the plant power records do not reflect this additional cost. Based on an 8 kW demand for the destruct unit, a power cost was estimated for off-gas destruction. The power cost for the entire ozone system was estimated to be $8,916 annually. When the cost of the materials, labor and power were combined, the annual operational cost totaled $12,270.

Sludge Handling

Sludge digestion, dewatering and disposal are included in this category. The following items make up the sludge handling process: digester basins, aerators, blowers, sludge pump, dewatering equipment and the sludge truck. The capital cost for this system totaled $453,850, or 15.3 percent of the total cost. Of this amount, approximately $120,970 went to the associated equipment, and $169,350 was directed to materials and labor for construction of the structures. Other capital costs of $163,530 were associated with piping, electrical systems, equipment controls and site preparation.

Supplies for the sludge handling system were, for the most part, related to sludge dewatering and disposal. The annual cost for chemical polymer was $3,318, based on dewatering 90 tons of sludge (dry wt. basis) per year. Also, about $184/year went to transportation of the sludge cake to ultimate disposal. Total cost for supplies were then $3,502 per year. The manpower requirement for sludge handling was 2.8 man-hours/day or 1,018 man-hours per year, for an annual cost of $5,599. Most of the manpower requirement went to drawing supernatant from the aerobic digesters and to operation and maintenance of the sludge dewatering system. The power demand of the sludge handling system was mostly due to the operation of the aerators and the blowers. An annual cost of $8,616 was allocated for the power requirements of sludge handling. The total operation cost, including supplies, labor and power, was $17,717 per year.

Miscellaneous

The remainder of the total capital cost of the plant, $391,470, was included in a miscellaneous category. The plant laboratory and associated equipment accounted for $59,630, and $331,840 went to material and labor costs for the plant administration and control building. Major equipment included in the main plant building included the standby generator, non-potable water supply system, and the heating and ventilation systems.

The majority of the plant expenditures for supplies could not be specifically divided among the previously discussed processes; consequently, they were presented in this subsection. Items included within this category were the following: operation supplies, repairs and maintenance, insurance, natural gas, lab chemicals, telephone, transportation, equipment rental and office supplies. The combined cost for these supplies was $22,311 per year.

Other manpower needs that were not discussed in the previous processes included management, vacations and the laboratory effort. A total of 7,950 man-hours per year were expended in these areas; however, reductions were made subsequent to the research project. The laboratory manpower decreased from 4,780 man-hours to 2,156 man-hours by reducing the various sampling and testing frequencies. Management manpower decreased from 2,000 man-hours to 600 man-hours. Because of these reductions and the reductions in activated sludge man-power, the vacation time also decreased from 1,170 man-hours to 717 man-hours. The scale down of the plant staff did not affect the plant operation, since the additional manpower was being directed toward the research effort. The miscellaneous manpower requirement following the research project decreased from the original 7,950 man-hours to 3,473 man-hours for an annual cost of $19,102 as opposed to $42,052 per year.

The miscellaneous power cost for the plant was $5,460 annually. Power for the laboratory, plant building and small equipment systems are included. The total operational cost for the miscellaneous category, excluding research associated costs, was $46,873 per year.

Summary of Cost Information

The UTSD plant was built for a design life of 20 years. A summary of the total capital cost for the plant is shown in Table 41. Also shown is the yearly capital cost for 20 years at a 6-1/4 percent interest rate, which is the bond interest rate for the UTSD plant. Using the design flow for the plant of 5,680 cu m/day (1.5 mgd) and the yearly capital cost of $263,330, the capital cost for wastewater treatment then became 12.7¢/cu m (48¢/1000 gal) treated.

TABLE 41. CAPITAL COST - UPPER THOMPSON WASTEWATER TREATMENT PLANT

Item	Cost ($)	Percent of Total
Lift Stations	189,720	6.4
Preliminary Treatment	270,540	9.1
Activated Sludge	569,400	19.2
Nitrification	364,360	12.3
Filtration	378,510	12.8
Ozone Disinfection	341,460	11.5
Sludge Handling	453,850	15.3
Miscellaneous	391,470	13.2
TOTAL	2,959,310 or $263,330 per year @ 6-1/4%* interest over 20 years.	100.0

*The UTSD bonded indebtedness is at a 6-1/4% interest rate.

A summary of the operating costs for the UTSD plant appears in Table 42. These costs reflect normal operating expenses and not those associated with the research project. The annual operating cost for the plant was $123,064.

The past records of plant flow show that, on the average, 662,375 cum (175 million gallons) of wastewater was treated per year which was 32 percent of the design flow. The resulting unit cost was then 18.6 ¢/cu m (70.3¢/1000 gal). Over 50 percent of this cost was associated with the two unit processes, activated sludge and sludge dewatering. Ten percent of the total operating cost was associated with ozone disinfection. It should be noted that the operation's unit cost of 18.6 ¢/cum (70.3 ¢/1000 gal) is greater than would occur at design flow rates. Treating flows of only 32 percent of design is inherently less efficient, even when 50 percent of most unit processes can be shut-down. Also, some reduction in the operations costs shown may evolve through further optimization of process control, but the costs shown are felt to fairly closely reflect the operating costs of the UTSD facility during the time period of the research project.

TABLE 42. ANNUAL OPERATIONS COST - UPPER THOMPSON WASTEWATER TREATMENT PLANT

Item	Supplies ($)	Manpower ($)	Power ($)	Total ($)	¢/1000 gal (actual flow)	%
Lift Stations	---	5,016	1,284	6,300	3.6	5.1
Preliminary Treatment	---	3,108	2,532	5,640	3.2	4.6
Activated Sludge	---	10,830	13,512	24,342	13.9	19.8
Nitrification	---	682	6,624	7,306	4.2	6.0
Filtration	---	2,508	108	2,616	1.5	2.1
Ozonation	1,000	2,354	8,916	12,270	7.0	10.0
Sludge Handling	3,502	5,599	8,616	17,717	10.1	14.4
Miscellaneous	22,311	19,102	5,460	46,873	26.8	38.0
	26,813	49,199	47,052	123,064	70.3	100.0

¢/1000 gal x 0.264 = ¢/cu m

SECTION 8

REFERENCES

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2. Hegg, B.A., K.L. Rakness, and J.R. Schultz, "A Demonstrated Approach for Improving Performance and Reliability of Biological Wastewater Treatment Plants," report prepared in partial fulfillment of EPA Contract No. 68-03-2224, by M & I, Inc., Fort Collins, Colorado, for U.S. EPA, Cincinnati, Ohio (1973).

3. McCarty, P.L., L. Beck, and P. St. Amant, "Biological Denitrification of Wastewater by Addition of Organic Materials. Proceedings of the 24th Industrial Waste Conference, May 6, 7, and 8, 1969, Lafayette, Indiana, Purdue University (1969).

4. Process Manual for Nitrogen Control, U.S. Environmental Protection Agency, Technology Transfer Publication (October 1975).

5. Hill, A.G. and H.T. Spencer, "Mass Transfer in Gas Sparged Ozone Reactor", Proceedings of the First International Symposium on Ozone for Water and Wastewater Treatment sponsored by the International Ozone Institute (1975).

6. Personal communication with Mr. Ed Opatken, MERL, Cincinnati, Ohio, September, 1978.

APPENDIX A

SUMMARY OF LABORATORY DATA - FLOW EQUALIZATION SYSTEM

																	Coliform - MF	
Period	Flow	Flow	Sample		D.O.	pH	pH	pH	BOD_5	COD	NH_3-N	TKN	NO_2NO_3-N	TSS	Total P	Alk.	Total	Fecal
	MGD	GPM	Point*		mg/l	Med.	Min.	Max.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	#/100 ml	#/100 ml
1976 Nov 28 - Dec 4	0.36	250	I		6.0	7.3	6.8	7.4	59	127	7.64	14.14		77	3.40	91.6	1.9×10^6	8.0×10^5
			E		4.4	7.1	7.1	7.3	45	228	8.22	19.85	0.22	128	4.22	94.0	1.4×10^6	6.5×10^5
			R															
Dec 5 - Dec 11	0.25	173	I		6.3	7.2	6.7	7.3	112	137	7.71	12.32		59	3.28	97.5	3.1×10^6	2.3×10^6
			E		5.6	7.2	7.1	7.3	150	135	7.02	11.05	1.04	87	3.76	77.5	2.3×10^6	2.2×10^5
			R															
Dec 12 - Dec 18	0.21	146	I		6.1	7.0	6.7	7.1	184	161	7.20	11.00		122	2.74	69.7	5.6×10^6	9.1×10^5
			E		6.6	7.1	7.0	7.2	139	153	7.20	11.90	0.93	77	3.00	73.4	3.4×10^6	6.6×10^5
			R															
Dec 19 - Dec 25	0.26	180	I		6.4	6.8	6.5	7.1	123	315	7.50	13.46		364	4.60	71.9	1.6×10^6	3.0×10^5
			E		5.7	7.0	6.9	7.2	90	217	7.80	15.40	0.03	77	3.82	66.2	1.0×10^6	3.8×10^5
			R															
Dec 26 - Jan 1	0.30	208	I		6.2	7.2	7.1	7.3	142	270	9.40	16.30		103	4.14	82.7	1.2×10^7	4.3×10^6
			E		5.1	7.3	7.3	7.4	132	248	9.83	16.23	0.03	92	4.18	84.2	4.2×10^6	6.5×10^5
			R															
1977 Jan 2 - Jan 8	0.30	208	I		6.4	7.1	6.8	7.1	92	217	6.80	14.36		110	4.73	69.8	2.6×10^6	5.5×10^5
			E		6.3	7.1	6.9	7.5	128	203	7.90	12.40	7.03	86	4.81	75.0	1.9×10^6	4.0×10^5
			R															
Jan 9 - Jan 15	0.45	312	I		7.1	6.6	6.2	7.3	93	148	6.32	10.60		103	3.94	65.5	2.0×10^6	6.5×10^5
			E		5.7	7.2	6.7	7.3	95	190	6.93	14.76	1.96	126	4.50	71.7	1.8×10^6	5.0×10^5
			R															
Jan 16 - Jan 22	0.62	430	I		7.1	7.1	6.6	7.7	65	143	5.70	9.63		83	2.89	58.9	2.3×10^6	1.0×10^6
			E		6.3	7.1	6.8	7.3	65	142	5.70	10.62	0.65	71	3.16	63.7	3.1×10^6	1.8×10^6
			R															
Jan 23 - Jan 29	0.50	347	I		6.6	7.2	7.0	7.2	115	198	5.93	12.10		112	3.20	62.7	1.2×10^6	5.4×10^5
			E		4.8	7.4	7.2	7.8	146	198	6.79	11.91	0.73	82	3.79	67.5	2.7×10^6	2.0×10^6
			R															
Jan 30 - Feb 5	0.47	327	I		6.0	7.0	6.7	7.3	141	200	7.30	14.71		100	3.24		2.3×10^6	1.2×10^6
			E		5.2	7.2	6.8	7.3	102	216	7.95	15.20	-	65	4.22	.03	3.5×10^6	8.0×10^5
			R															

* I = Influent to Thompson Lift Station
E = Effluent from Equalization Basin
R = Percent removal where applicable

APPENDIX A (CONTINUED)

																	Coliform - MF	
Period	Flow	Flow	Sample		D.O.	pH	pH	pH	BOD$_5$	COD	NH$_3$-N	TKN	NO$_2$NO$_3$-N	TSS	Total P	Alk.	Total	Fecal
	MGD	GPM	Point*		mg/l	Med.	Min.	Max.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	#/100 ml	#/100 ml
1977 Feb 6 - Feb 12	0.45	312	I		6.6	7.2	6.6	7.4	102	205	6.20	12.37		306	4.27	89.6	$2.8x10^6$	$8.0x10^5$
			F		5.6	7.2	6.8	7.3	90	316	7.17	17.20	0.64	282	3.94	75.6	$1.5x10^6$	$7.2x10^5$
			R															
Feb 13 - Feb 19	0.48	333 •	I		6.2	7.2	7.1	7.3	160	182	6.59	12.77		184	3.26	91.0	$6.8x10^6$	$2.4x10^6$
			E		5.1	7.3	7.0	7.5	155	185	6.91	12.37	0.50	73	3.31	74.0	$2.2x10^6$	$1.2x10^6$
			R															
Feb 20 - Feb 26	0.48	333	I		6.4	7.1	7.2	7.3	82	246	7.09	12.49		128	3.88	96.5	$2.0x10^6$	$6.5x10^5$
			E		5.0	7.2	7.0	9.3	121	291	7.09	14.67	0.71	118	4.26	79.6	$2.6x10^6$	$1.4x10^5$
			R															
Feb 27 - Mar 5	0.48	333	I		6.5	7.2	7.1	7.3	118	204	7.20	13.19		255	3.69	112.3	$1.6x10^6$	$2.5x10^5$
			E		4.6	7.1	7.1	7.2	231	368	6.97	20.52	0.46	340	4.69	83.8	$9.5x10^5$	$1.5x10^5$
			R															
Mar 6 - Mar 12	0.48	333	I		7.1	7.0	6.6	7.3	106	208	6.92	12.25		249	4.14	98.0	$1.7x10^6$	$2.4x10^5$
			E		4.4	7.0	6.8	7.3	131	299	7.38	12.77	1.36	149	4.54	79.0	$1.5x10^6$	$1.7x10^5$
			R															
Mar 13 - Mar 19	0.48	333	I		6.4	7.1	6.5	7.2	148	222	10.06	13.74		136	6.02	93.0	$7.7x10^5$	$6.7x10^4$
			E		4.1	7.1	7.0	7.2	202	270	8.43	16.05	0.59	172	5.49	79.5	$1.4x10^6$	$1.4x10^5$
			R															
Mar 20 - Mar 26	0.40	283	I		6.5	7.0	6.7	7.3	94	244	8.17	14.88		126	3.86	96.0	$1.3x10^6$	$5.7x10^4$
			E		4.7	7.2	7.1	7.3	180	304	8.29	17.00	0.13	162	4.42	83.5	$6.2x10^5$	$8.0x10^4$
			R															
Mar 27 - Apr 2	0.48	333	I		6.4	7.1	6.8	7.3	192	263	7.96	14.51		126	4.51	87.0	$1.0x10^6$	$3.0x10^5$
			E		4.2	7.1	7.0	7.2	119	180	7.91	11.94	1.22	76	4.11	82.2	$2.1x10^6$	$1.0x10^5$
			R															
Apr 3 - Apr 9	0.48	333	I		6.0	7.3	7.0	8.1	109	228	9.28	14.54		78	3.99	103.0	$1.5x10^6$	$2.4x10^5$
			E		5.0	7.3	7.2	8.1	60	129	9.02	13.40	1.60	35	3.96	87.0	$1.0x10^6$	$2.0x10^5$
			R															
Apr 10 - Apr 16	0.34	235	I		6.0	7.1	7.0	7.6	118	231	8.33	14.10		146	3.93	92.2	$1.8x10^6$	$1.2x10^6$
			E		4.2	7.2	7.1	7.6	92	356	9.17	19.86	1.17	217	3.50	90.2	$1.3x10^7$	$1.8x10^6$
			R															

APPENDIX A (CONTINUED)

																	Coliform - MF	
Period	Flow	Flow	Sample		D.O.	pH	pH	pH	BOD$_5$	COD	NH$_3$-N	TKN	NO$_2$NO$_3$-N	TSS	Total P	Alk.	Total	Fecal
	MGD	GPM	Point*		mg/l	Med.	Min.	Max.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	#/100 ml	#/100 ml
1977 Apr 17 - Apr 23	0.42	262	I		6.7	7.0	6.5	7.4	166	227	8.89	14.24		101	4.29	87.9	$7.7\mathrm{x}10^6$	$1.5\mathrm{x}10^6$
			E		4.6	7.1	7.0	7.3	486	297	8.65	18.20	0.97	184	4.91	78.4	$5.1\mathrm{x}10^6$	$2.2\mathrm{x}10^6$
			R															
Apr 24 - Apr 30	0.66	375	I		5.8	7.1	6.5	7.1	132	195	9.65	12.54		83	5.59	69.3	$4.5\mathrm{x}10^6$	$1.4\mathrm{x}10^6$
			E		3.8	7.1	7.0	7.2	92	187	8.03	14.25	2.22	56	5.59	73.5	$1.9\mathrm{x}10^6$	$4.5\mathrm{x}10^5$
			R															
May 1 - May 7	0.42	262	I		5.7	7.2	7.2	7.3	154	222	8.10	14.10		110	3.92	81.9	$4.4\mathrm{x}10^6$	$8.7\mathrm{x}10^5$
			E		4.5	7.3	7.2	7.4	198	201	8.34	14.22	0.89	92	4.13	80.9	$2.9\mathrm{x}10^6$	$1.2\mathrm{x}10^6$
			R															
May 8 - May 14	0.52	365	I		5.3	7.2	7.2	7.4	156	272	7.47	14.58		96	4.71	76.1	$6.0\mathrm{x}10^6$	$4.7\mathrm{x}10^5$
			E		1.6	7.0	6.9	7.1	145	234	7.52	16.26	1.08	121	5.15	73.5	$6.5\mathrm{x}10^6$	$1.1\mathrm{x}10^6$
			R															
May 15 - May 21	0.52	365	I		5.1	7.2	7.1	7.4	167	299	9.76	17.48		121	5.79	85.0	$3.9\mathrm{x}10^6$	$1.3\mathrm{x}10^6$
			E		1.5	7.2	7.0	7.2	204	244	9.77	18.16	0.57	135	5.70	90.3	$6.4\mathrm{x}10^6$	$1.0\mathrm{x}10^6$
			R															
May 22 - May 28	0.48	333	I		5.1	7.4	7.3	8.3	222	380	13.99	21.69		155	5.06	122	$3.3\mathrm{x}10^6$	$6.8\mathrm{x}10^5$
			E		2.2	7.4	7.2	7.6	222	264	13.13	18.90	0.31	131	5.03	98.7	$2.6\mathrm{x}10^6$	$1.2\mathrm{x}10^6$
			R															
May 29 - Jun 4	0.76	525	I		4.8	7.2	7.0	7.3	150	1112	16.72	21.40		178	5.72	91.4	$7.8\mathrm{x}10^6$	$1.8\mathrm{x}10^6$
			E		2.0	7.1	6.9	7.3	178	373	15.82	24.77	0.11	132	6.20	103	$6.3\mathrm{x}10^6$	$3.2\mathrm{x}10^6$
			R															
Jun 5 - Jun 11	0.94	652	I		3.7	7.2	7.1	8.7	-	317	19.30	29.33		164	6.46	138	$3.5\mathrm{x}10^6$	$2.3\mathrm{x}10^6$
			E		1.2	7.2	6.9	7.3	-	273	20.71	30.51	0.10	142	6.27	140	$3.5\mathrm{x}10^6$	$2.6\mathrm{x}10^6$
			R															
Jun 12 - Jun 18	1.12	778	I		-	7.1	6.9	7.2	-	381	23.61	34.07		171	8.93	151	$1.2\mathrm{x}10^7$	$3.5\mathrm{x}10^6$
			E		-	7.2	7.1	7.4	-	361	21.92	34.52	0.60	209	6.88	151	$1.5\mathrm{x}10^7$	$3.8\mathrm{x}10^6$
			R															
Jun 19 - Jun 25			I															
			E		no analyses run													
			R															

APPENDIX A (CONTINUED)

																	Coliform - MF	
Period	Flow	Flow	Sample		D.O.	pH	pH	pH	BOD$_5$	COD	NH$_3$-N	TKN	NO$_2$NO$_3$-N	TSS	Total P	Alk.	Total	Fecal
	MGD	GPM	Point*		mg/l	Med.	Min.	Max.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	#/100 ml	#/100 ml
1977 June 26-July 2	1.11	763	I		no analyses run													
			E															
			R															
July 3-July 9	1.05	729	I		0.9	7.1	7.0	7.1	---	607	23.35	32.05	---	692	6.24	147	2.2x10^{7}	6.0x10^{6}
			E		0.3	7.1	7.0	7.2	---	509	23.89	34.62	---	464	6.14	143	1.4x10^{7}	5.0x10^{6}
			R															
July 10-July 16	0.92	639	I		0.4	7.3	7.2	7.4	---	554	29.91	---	---	272	6.45	189	---	---
			E		0.1	7.3	7.2	7.8	380	409	29.60	80.09	0.01	634	6.34	177	---	---
			R															
July 17-July 23	0.98	680	I		0.9	7.2	7.1	7.3	494	1552	25.52	43.28	---	273	6.06	162	2.2x10^{7}	7.9x10^{6}
			E		0.1	7.2	7.1	7.4	368	526	26.58	41.28	0.02	280	6.45	160	2.2x10^{7}	8.9x10^{6}
			R															
July 24-July 30	1.02	708	I		0.3	7.2	7.1	7.4	890	1288	24.49	38.06	---	480	6.29	153	6.6x10^{6}	2.3x10^{6}
			E		0.0	7.3	7.1	7.4	305	399	22.70	37.22	0.38	210	5.76	154	7.2x10^{6}	3.5x10^{6}
			R															
July 31-Aug.6	1.12	781	I		0.0	7.2	7.1	7.3	695	610	28.22	42.55	---	196	7.84	170	---	---
			E		0.0	7.4	7.3	8.0	260	350	26.99	39.63	---	162	9.32	168	---	---
			R															
Aug.7-Aug.13	0.93	646	I		0.0	7.3	7.1	7.4	628	684	26.54	41.83	---	227	7.50	167	---	---
			E		0.0	7.3	7.2	7.5	349	480	25.47	38.53	0.02	188	7.72	161	---	---
			R															
Aug.14-Aug.20	1.03	713	I		0.0	7.3	7.2	7.4	620	388	22.46	37.58	---	210	6.48	153	---	---
			E		0.0	7.2	7.1	7.8	920	335	20.64	32.64	0.16	143	6.49	146	---	---
			R															
Aug.21-Aug.27	0.77	537	I		0.6	7.0	6.8	7.3	305	485	25.18	34.50	---	204	6.53	172	1.2x10^{7}	7.6x10^{5}
			E		0.0	7.1	6.8	8.2	338	510	22.60	36.33	0.01	162	7.61	250	2.6x10^{7}	1.8x10^{6}
			R															
Aug.28-Sept.3	0.49	340	I		1.0	7.1	6.9	7.4	405	587	25.18	36.51	---	376	9.76	160	2.4x10^{6}	1.3x10^{6}
			E		0.2	7.1	6.7	7.7	254	598	27.11	45.25	0.04	389	12.32	158	1.5x10^{7}	2.2x10^{6}
			R															

APPENDIX A (CONTINUED)

																	Coliform - MF	
Period	Flow	Flow	Sample		D.O.	pH	pH	pH	BOD$_5$	COD	NH$_3$-N	TKN	NO$_2$NO$_3$-N	TSS	Total P	Alk.	Total	Fecal
	MGD	GPM	Point*		mg/l	Med.	Min.	Max.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	#/100 ml	#/100 ml
1977 Sept. 4-Sept.10	0.54	375	I		0.9	7.0	6.9	7.3	235	453	16.51	26.87	-	222	6.00	123	$1.7x10^7$	$4.3x10^6$
			E		0.1	7.1	6.8	7.2	195	512	16.15	29.24	0.18	278	6.08	127	$1.8x10^7$	$3.0x10^6$
			R															
Sept. 11-Sept.17	0.56	392	I		0.8	7.0	6.8	7.3	228	388	10.56	20.33	-	210	6.14	113	$1.5x10^7$	$5.3x10^6$
			E		0.2	7.0	6.7	7.9	262	296	11.31	20.68	0.04	244	7.44	105	$1.4x10^7$	$2.2x10^6$
			R															
Sept. 18-Sept.24	0.58	402	I		0.8	7.1	6.9	7.5	318	432	14.04	22.41	-	178	5.23	126	$9.5x10^6$	$1.6x10^6$
			E		0.1	7.1	7.0	7.6	318	361	15.02	24.73	-	162	5.47	133	$9.9x10^6$	$3.5x10^6$
			R															
Sept. 25-Oct. 1	0.49	311	I		1.5	6.9	6.5	7.3	468	692	22.01	37.16	-	400	9.18	152	$1.3x10^6$	$3.0x10^5$
			E		0.5	7.1	6.7	7.6	250	441	22.80	34.56	0.01	294	9.29	152	$3.9x10^7$	$2.7x10^6$
			R															
Oct. 2-Oct. 8	0.40	270	I		2.3	7.0	6.8	7.3	205	433	11.23	21.78	-	145	6.10	106	$3.2x10^7$	$1.8x10^6$
			E		0.5	7.0	6.7	7.1	250	325	12.55	22.49	0.02	104	6.73	117	$1.2x10^7$	$1.6x10^6$
			R															
Oct. 9-Oct. 15	0.40	279	I		2.8	7.0	7.2	6.9	175	362	10.17	19.23	-	171	6.90	109	$2.2x10^6$	$1.3x10^6$
			E		0.8	7.0	6.9	7.1	-	240	11.81	24.72	1.03	145	9.06	124	$1.3x10^6$	$8.5x10^6$
			R															
Oct. 16-Oct. 22	0.36	252	I		3.2	7.1	6.8	7.2	185	432	11.78	21.45	-	188	5.68	110	-	-
			E		1.2	7.0	6.8	7.1	125	344	12.49	22.07	0.01	167	6.32	114	-	-
			R															
Oct. 23-Oct. 29	0.37	251	I		3.3	7.1	6.9	7.2	278	530	14.81	27.80	-	244	6.37	115	$1.5x10^7$	$2.9x10^6$
			E		1.6	7.0	6.7	7.1	273	430	14.95	28.44	-	223	7.51	112	$1.2x10^7$	$1.4x10^6$
			R															
Oct. 30-Nov. 5	0.36	250	I		3.1	7.0	6.6	7.3	305	564	16.61	29.91	-	241	6.85	95.5	$6.0x10^6$	$1.6x10^6$
			E		0.8	7.1	7.0	7.4	300	496	16.50	29.07	0.44	217	7.57	104	$1.0x10^7$	$1.6x10^6$
			R															
Nov. 6-Nov. 12	0.27	189	I		4.0	7.2	6.7	7.9	520	501	13.51	23.77	-	259	7.89	113	$4.9x10^6$	$7.5x10^5$
			E		1.3	7.1	6.8	7.2	545	472	15.55	24.65	0.13	318	7.93	125	$1.7x10^6$	$3.9x10^5$
			R															

APPENDIX A (CONTINUED)

																	Coliform - MF	
Period	Flow	Flow	Sample		D.O.	pH	pH	pH	BOD_5	COD	NH_3-N	TKN	NO_2NO_3-N	TSS	Total P	Alk.	Total	Fecal
	MGD	GPM	Point*		mg/l	Med.	Min.	Max.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	#/100 ml	#/100 ml
1977 Nov.13-Nov.19	0.31	215	I		4.5	7.1	6.9	7.3	260	714	12.39	24.98	-	286	7.84	159	$1.7x10^6$	$3.6x10^5$
			E		1.4	7.0	6.9	7.1	255	677	13.33	27.29	0.84	345	7.84	115	$6.3x10^6$	$2.2x10^6$
			R															
Nov.20-Nov.26	0.32	222	I		5.5	7.1	6.9	7.3	180	333	12.42	23.24	-	177	6.37	122	$4.4x10^6$	$3.4x10^6$
			E		1.7	6.9	6.8	7.1	230	570	13.62	27.10	0.03	188	7.30	114	$5.3x10^6$	$1.5x10^6$
			R															
Nov.27-Dec.3	0.30	208	I		5.2	7.0	6.9	7.1	210	433	10.68	23.94	-	210	5.78	96.0	$1.1x10^7$	$6.1x10^5$
			E		2.8	7.0	6.9	7.1	290	407	14.61	28.39	0.26	249	6.72	114	$2.1x10^7$	$3.1x10^6$
			R															
Dec.4-Dec.10	0.32	222	I		5.4	7.0	7.2	7.3	530	481	14.53	24.20	-	321	5.08	45.4	$7.3x10^6$	$1.8x10^6$
			E		2.0	7.1	7.0	7.1	153	529	15.05	25.33	0.16	233	5.93	43.5	$1.9x10^7$	$1.7x10^6$
			R															
Dec.11-Dec.17	0.31	215	I		4.7	7.4	7.1	7.8	282	506	13.43	25.35	-	208	6.00	62.3	$8.0x10^6$	$5.3x10^6$
			E		2.3	7.3	7.2	7.4	264	364	15.16	27.98	1.07	222	6.72	66.1	$1.8x10^7$	$2.6x10^6$
			R															
Dec.18-Dec.24	0.29	201	I		Sampling at lift station discontinued.													
			E															
			R															
			I															
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APPENDIX B

SUMMARY OF LABORATORY DATA - ACTIVATED SLUDGE PROCESS

																	Coliform - MF	
Period	Flow	Recycle	Sample	Turbidity	D.O.	pH	pH	pH	BOD_5	COD	NH_3-N	TKN	NO_2NO_3-N	TSS	Total P	Alk.	Total	Fecal
	MGD	MGD	Point*	NTU	mg/l	Med.	Min.	Max.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	#/100 ml	#/100 ml
1976 June 27 - July 3	0.15	0.26	I		-	-	-	-	163	353	38.50	52.25	-	161	8.80	242		
			E		-	-	-	-	27	63.8	7.65	11.73	15.00	28	7.13	103	9.5×10^5	3.0×10^4
			R											82%	19%	57%		
July 11 - July 17	0.78	0.36	I		2.9	7.6	7.4	7.6	210	405	25.30	44.60	-	241	6.93	-		
			E		1.4	6.5	6.0	6.9	56	119	8.60	16.70	5.30	51	5.27	-	1.0×10^7	1.1×10^6
			R						73%	71%	66%	63%		79%	24%			
July 18 - July 24	0.56	0.36	I		2.8	7.6	7.6	7.7	158	320	27.70	31.65	0.02	108	9.80	-		
			E		1.6	6.1	5.8	6.4	80	178	6.40	13.90	1.50	75	8.60	-	7.6×10^6	4.4×10^6
			R						49%	44%	77%	56%		31%	12%			
July 25 - July 31	0.58	0.39	I		2.1	7.8	5.5	9.0	185	394	29.80	-	0.49	182	10.50	-	1.8×10^7	3.1×10^6
			E		1.3	6.6	6.2	7.3	62	132	3.60	10.50	0.12	72	7.50	-	5.1×10^6	1.7×10^5
			R						66%	66%	88%			60%	28%			
Aug 8 - Aug 14	0.15	0.16	I		3.8	7.4	7.3	7.5	-	361	41.70	44.00	-	242	-	-	-	-
			E		2.3	5.7	5.3	6.6	-	70.0	5.15	8.30	-	27	-	-	-	-
			R							81%	88%	81%		89%				
Aug 15 - Aug 21	0.30	0.28	I		3.9	7.4	7.3	7.5	129	388	25.60	30.50	-	110	-	-	-	-
			E		2.4	5.5	5.2	7.1	55	92.7	2.25	9.60	21.40	47	-	-	-	-
			R						42%	76%	91%	69%		57%				
Aug 22 - Aug 28	0.54	0.40	I		4.8	7.3	7.2	7.3	65	240	23.30	31.80	-	263	-	-	-	-
			E		2.9	6.0	5.6	7.7	44	74.0	3.40	7.80	21.70	46	-	-	-	-
			R						33%	69%	85%	75%		83%				
Aug 29 - Sept 4	0.38	0.21	I		4.0	7.2	7.1	7.3	255	221	24.00	30.30	-	631	-	-	-	-
			E		2.9	6.2	6.0	6.5	37	65.3	2.20	5.40	16.50	22	-	-	-	-
			R						85%	70%	91%	82%		97%				
Sept 5 - Sept 11	0.48	0.27	I		3.1	7.1	6.5	8.4	-	-	-	-	-	-	-	-	-	-
			E		2.6	5.8	5.4	6.2	-	-	-	-	-	-	-	-	-	-
			R															
Sept 12 - Sept 18	0.38	0.38	I		3.9	6.8	6.2	7.0	-	165	-	-	-	-	-	-	-	-
			E		2.3	5.8	5.5	6.0	-	41.0	2.10	13.80	11.90	-	-	-	-	-
			R							75%								

* I = Flow from Equalization Basin
E = Effluent from Activated Sludge Process
R = Percent removal where applicable

APPENDIX B (CONTINUED)

																	Coliform - MF	
Period	Flow	Recycle	Sample	Turbidity	D.O.	pH	pH	pH	BOD_5	COD	NH_3-N	TKN	NO_2NO_3-N	TSS	Total P	Alk.	Total	Fecal
	MGD	MGD	Point*	NTU	mg/1	Med.	Min.	Max.	mg/1	mg/1	mg/1	mg/1	mg/1	mg/1	mg/1	mg/1	#/100 ml	#/100 ml
1976 Sept 19 - Sept 25	0.54	0.49	I		4.1	6.8	6.7	7.0	233	220	16.24	24.86	-	80	-	74.7	$2.9x10^6$	$9.1x10^4$
			E		3.1	5.9	5.7	6.0	65	68	0.78	3.58	12.60	14	-	11.7	$7.2x10^5$	$3.2x10^4$
			R						72%	69%	32%	86%		82%		84%		
Sept 26 - Oct 2	0.48	0.46	I		3.9	6.7	6.6	6.8	98	-	-	-	-	60	-	-	-	-
			E		3.5	5.7	5.0	6.2	7.1	-	-	-	11.50	7.0	-	-	-	-
			R						93%					88%				
Oct 3 - Oct 9	0.40	0.40	I		3.8	6.6	6.3	8.2	345	197	-	-	-	80	-	-	-	-
			E		3.1	5.8	4.7	5.9	39	51.9	-	7.57	12.20	36	-	-	-	-
			R						89%	74%				55%				
Oct 10 - Oct 16	0.26	0.22	I		3.7	6.9	6.6	7.7	279	248	12.40	22.80	1.75	236	6.80	110	$2.5x10^6$	$3.8x10^5$
			E		4.5	6.2	5.9	6.8	22	48.2	0.28	3.60	9.85	42	5.40	26.4	$5.2x10^4$	$3.8x10^4$
			R						92%	81%	98%	40%		82%	21%	76%		
Oct 17 - Oct 23	0.22	0.18	I		4.4	6.3	6.2	6.7	96	156	8.18	15.70	-	48	2.30	105	$8.1x10^5$	$2.2x10^4$
			E		4.2	5.7	5.52	6.0	32	60.1	-	3.55	14.40	33	2.30	31.3	$2.0x10^5$	$6.6x10^3$
			R						66%	61%		77%		29%	0%	70%		
Oct 24 - Oct 30	0.18	0.16	I		3.9	6.2	6.0	6.3	118	178	8.00	15.35	-	68	1.80	40.4	$1.0x10^7$	$2.9x10^4$
			E		5.5	5.7	5.3	6.3	24	58.6	0.33	5.10	14.39	33	1.90	19.4	$3.5x10^5$	$5.8x10^3$
			R						79%	67%	96%	67%		52%		52%		
Oct 31 - Nov 6	0.23	0.32	I		4.4	6.5	6.3	6.6	72	171	9.31	15.44	-	67	3.60	105	-	-
			E		5.5	5.8	5.7	6.5	22	58.8	0.98	4.10	21.18	26	3.98	27.0	$1.5x10^5$	$7.6x10^3$
			R						69%	66%	89%	73%		62%		74%		
Nov 7 - Nov 13	0.21	0.13	I		5.1	5.9	5.8	6.2	94	198	9.54	14.15	-	94	4.34	94.0	$6.0x10^6$	$4.9x10^5$
			E		4.0	5.9	5.8	6.2	21	73.4	3.73	3.73	11.96	26	3.59	30.0	$3.7x10^5$	$1.0x10^5$
			R						78%	63%	61%	74%		72%	17%	68%		
Nov 14 - Nov 20	0.28	0.14	I		5.3	6.7	6.3	7.6	62	223	8.78	15.33	0.14	103	4.15	95.0	$3.6x10^6$	$9.9x10^5$
			E		3.7	6.3	5.6	6.9	40	56.1	1.94	4.84	8.49	32	3.51	38.3	$4.4x10^5$	$5.0x10^4$
			R						35%	75%	78%	68%		69%	15%	60%		
Nov 21 - Nov 27	0.20	0.13	I		5.4	7.2	6.7	7.2	177	166	8.70	14.10	0.30	124	3.40	99.7	$1.4x10^6$	$1.2x10^6$
			E		3.5	6.6	6.5	7.3	64	62.1	5.60	5.80	5.50	35	2.80	59.0	$3.6x10^5$	$4.3x10^5$
			R						64%	63%	36%	59%		72%	18%	41%		

APPENDIX B (CONTINUED)

																Coliform - MF	
Period	Flow	Recycle	Sample	Turbidity	D.O.	pH	pH	pH	BOD_5	COD	NH_3-N	TKN	NO_2NO_3-N	TSS	Total P	Alk.	Total	Fecal
	MGD	MGD	Point*	NTU	mg/l	Med.	Min.	Max.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	#/100 ml	#/100 ml
1976			I		4.4	7.1	7.0	7.3	45	228	8.22	19.85	0.22	128	4.22	94.0	$1.4x10^{6}$	$6.5x10^{5}$
Nov 28 - Dec 4	0.36	0.19	E	4.3	3.7	6.6	6.6	7.0	26	17.0	4.38	5.16	2.44	17	3.17	56.5	$2.0x10^{5}$	$9.0x10^{4}$
			R						42%	93%	47%	74%		87%	25%	40%		
			I		5.6	7.2	7.1	7.3	150	135	7.02	11.05	1.04	87	3.76	77.5	$2.3x10^{6}$	$2.2x10^{5}$
Dec 5 - Dec 11	0.25	0.14	F	4.6	4.7	6.6	6.5	6.9	32	29.0	3.88	6.02	4.27	20	2.83	52.5	$7.3x10^{4}$	$3.7x10^{3}$
			R						79%	78%	45%	46%		78%	25%	32%		
			I		6.6	7.1	7.0	7.2	139	153	7.20	11.90	0.93	77	3.00	73.4	$3.4x10^{6}$	$6.6x10^{5}$
Dec 12 - Dec 18	0.21	0.12	E	3.8	3.5	6.5	6.4	6.6	37	39.3	4.00	4.70	5.20	16	2.58	46.9	$9.2x10^{4}$	$7.1x10^{3}$
			R						73%	74%	44%	61%		79%	14%	36%		
			I		5.7	7.0	6.9	7.2	90	217	7.80	15.40	0.03	77	3.82	66.2	$1.0x10^{6}$	$3.8x10^{5}$
Dec 19 - Dec 25	0.26	0.15	E	3.8	4.0	6.6	6.2	6.8	26	43.8	5.93	6.58	0.73	15	2.84	55.4	$1.2x10^{5}$	$3.2x10^{4}$
			R						71%	80%	24%	57%		81%	26%	16%		
			I		5.1	7.3	7.3	7.4	132	248	9.83	16.23	0.03	92	4.18	84.2	$4.2x10^{6}$	$6.5x10^{5}$
Dec 26 - Jan 1	0.30	0.17	E	4.0	2.8	6.8	6.7	6.9	33	46.4	13.09	9.95	0.84	16	3.15	77.6	$5.1x10^{5}$	$5.9x10^{4}$
			R						75%	81%		39%		83%	25%	8%		
1977			I		6.3	7.1	6.9	7.5	128	203	7.90	12.40	7.03	86	4.81	75.0	$1.9x10^{6}$	$4.0x10^{5}$
Jan 2 - Jan 8	0.30	0.19	E	4.4	4.5	6.8	6.8	6.9	30	48.8	6.00	8.94	6.36	14	4.13	65.6	$2.4x10^{5}$	$5.3x10^{4}$
			R						77%	76%	24%	28%		84%	14%	13%		
			I		5.7	7.2	6.7	7.3	95	190	6.93	14.76	1.96	126	4.50	71.7	$1.8x10^{6}$	$5.0x10^{5}$
Jan 9 - Jan 15	0.45	0.28	E	4.0	5.6	6.8	6.8	7.2	31	42.4	5.89	7.00	5.17	20	3.25	67.9	$8.0x10^{4}$	$2.4x10^{4}$
			R						68%	78%	15%	53%		84%	28%	5%		
			I		6.3	7.1	6.8	7.3	65	142	5.70	10.62	0.65	71	3.16	63.7	$3.1x10^{6}$	$1.8x10^{6}$
Jan 16 - Jan 22	0.62	0.41	E	4.2	5.0	6.9	6.8	7.0	18	36.5	5.63	7.41	1.22	11	2.62	61.3	$1.2x10^{5}$	$3.3x10^{4}$
			R						73%	74%	1%	30%		84%	17%	4%		
			I		4.8	7.4	7.2	7.8	146	198	6.79	11.91	0.73	82	3.79	67.5	$2.7x10^{6}$	$2.0x10^{6}$
Jan 23 - Jan 29	0.50	0.28	E	6.3	4.0	7.2	6.8	7.8	38	52.7	6.58	7.93	0.97	27	3.07	61.8	$2.6x10^{5}$	$8.2x10^{4}$
			R						74%	73%	3%	33%		67%	19%	8%		
			I		5.2	7.2	6.8	7.4	102	216	7.95	15.20	-	65	4.22	103	$3.5x10^{6}$	$8.0x10^{5}$
Jan 30 - Feb 5	0.47	0.19	E	4.3	3.1	7.0	6.8	7.3	23	42.5	7.65	10.47	0.86	16	3.15	71.2	$9.2x10^{4}$	$1.4x10^{4}$
			R						78%	80%	4%	31%		75%	25%	31%		

APPENDIX B (CONTINUED)

																	Coliform - MF	
Period	Flow	Recycle	Sample	Turbidity	D.O.	pH	pH	pH	BOD$_5$	COD	NH$_3$-N	TKN	NO$_2$NO$_3$-N	TSS	Total P	Alk.	Total	Fecal
	MGD	MGD	Point*	NTU	mg/l	Med.	Min.	Max.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	#/100 ml	#/100 ml
1977 Feb 6 - Feb 12	0.45	0.30	I		5.6	7.2	6.8	7.3	90	316	7.17	17.20	0.64	282	3.94	75.6	1.5×10^{6}	7.2×10^{5}
			E	7.4	3.5	6.9	6.8	7.1	21	48.8	7.44	9.86	1.97	33	2.39	69.7	1.0×10^{5}	3.6×10^{4}
			R						77%	85%		43%		88%	39%	8%		
Feb 13 - Feb 19	0.48	0.34	I		5.1	7.3	7.0	7.5	155	185	6.91	12.37	0.50	73	3.31	74.0	2.2×10^{6}	1.2×10^{6}
			E	3.9	4.3	6.9	6.9	7.5	38	40.0	7.36	9.71	0.39	16	2.63	73.0	1.0×10^{5}	4.5×10^{4}
			R						75%	78%		22%		79%	21%	1%		
Feb 20 - Feb 26	0.48	0.32	I		5.0	7.2	7.0	9.3	121	291	7.09	14.67	0.71	118	4.26	79.6	2.6×10^{6}	1.4×10^{5}
			E	4.1	3.9	6.9	6.7	6.9	14	46.4	6.61	11.25	0.98	17	3.03	73.6	5.2×10^{5}	3.3×10^{4}
			R						88%	84%	7%	23%		86%	29%	8%		
Feb 27 - Mar 5	0.48	0.34	I		4.6	7.1	7.1	7.2	231	368	6.97	20.52	0.46	340	4.69	83.8	9.5×10^{5}	1.5×10^{5}
			E	4.3	4.9	6.9	6.7	7.0	26	48.6	7.06	10.07	0.74	22	2.99	74.8	5.0×10^{4}	5.5×10^{3}
			R						89%	87%		51%		94%	36%	11%		
Mar 6 - Mar 12	0.48	0.38	I		4.4	7.0	6.8	7.3	131	299	7.38	12.77	1.36	149	4.54	79.0	1.5×10^{6}	1.7×10^{5}
			E	4.8	5.4	6.7	6.7	6.8	19	51.5	7.24	9.75	2.95	16	3.98	74.5	9.2×10^{4}	9.2×10^{3}
			R						85%	83%	2%	24%		89%	12%	6%		
Mar 13 - Mar 19	0.48	0.41	I		4.1	7.1	7.0	7.2	202	270	8.43	16.05	0.59	172	5.49	79.5	1.4×10^{6}	1.4×10^{5}
			E	5.6	5.3	6.7	6.7	6.8	38	51.0	6.89	10.14	1.69	24	4.64	70.0	7.2×10^{4}	1.3×10^{4}
			R						81%	81%	18%	37%		86%	15%	12%		
Mar 20 - Mar 26	0.40	0.30	I		4.7	7.2	7.1	7.3	180	304	8.29	17.00	0.13	162	4.42	83.5	6.2×10^{5}	8.0×10^{4}
			E	5.5	5.1	6.8	6.7	6.9	26	56.5	7.04	10.04	1.44	21	3.01	74.5	7.9×10^{5}	1.1×10^{4}
			R						86%	81%	15%	41%		87%	32%	11%		
Mar 27 - Apr 2	0.48	0.36	I		4.2	7.1	7.0	7.2	119	180	7.91	11.94	1.22	76	4.11	82.2	2.1×10^{6}	1.0×10^{5}
			E	5.5	5.0	6.8	6.7	7.0	26	51.0	6.90	10.44	2.35	19	3.04	76.0	6.7×10^{5}	1.8×10^{5}
			R						78%	72%	13%	12%		75%	26%	8%		
Apr 3 - Apr 9	0.48	0.28	I		5.0	7.3	7.2	8.1	60	129	9.02	13.40	1.60	35	3.96	87.0	1.0×10^{6}	2.0×10^{5}
			E	6.1	4.2	6.9	6.8	7.0	30	50.1	8.88	10.46	2.47	16	3.26	72.7	6.7×10^{5}	9.7×10^{4}
			R						50%	62%	2%	22%		54%	18%	16%		
Apr 10 - Apr 16	0.34	0.17	I		4.2	7.2	7.1	7.6	92	356	9.17	19.86	1.17	217	3.50	90.2	1.3×10^{7}	1.8×10^{6}
			E	7.9	4.4	6.8	6.7	7.4	21	54.6	6.08	10.64	1.53	23	3.15	78.8	6.5×10^{5}	1.3×10^{5}
			R						77%	85%	34%	50%		89%	10%	13%		

APPENDIX B (CONTINUED)

																	Coliform - MF	
Period	Flow	Recycle	Sample	Turbidity	D.O.	pH	pH	pH	BOD$_5$	COD	NH$_3$-N	TKN	NO$_2$NO$_3$-N	TSS	Total P	Alk.	Total	Fecal
	MGD	MGD	Point*	NTU	mg/l	Med.	Min.	Max.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	#/100 ml	#/100 ml
1977 Apr 17 - Apr 23	0.42	0.32	I		4.6	7.1	7.0	7.3	486	297	8.65	18.20	0.97	184	4.91	78.4	$1.5x10^6$	$2.2x10^6$
			E	9.9	4.4	6.7	6.5	6.9	40	55.2	7.62	10.82	1.25	19	3.53	96.8	$9.6x10^5$	$3.2x10^5$
			R						92%	81%	12%	40%		89%	28%			
Apr 24 - Apr 30	0.66	0.64	I		3.8	7.1	7.0	7.2	92	187	8.03	14.25	2.22	56	5.59	73.5	$1.9x10^6$	$4.5x10^5$
			E	6.5	4.9	6.7	6.6	6.8	20	63.1	7.19	9.78	1.84	15	5.59	75.6	$3.7x10^5$	$3.8x10^4$
			R						78%	66%	10%	31%		73%	0%			
May 1 - May 7	0.42	0.29	I		4.5	7.3	7.2	7.4	198	201	8.34	14.22	0.89	92	4.13	80.9	$2.9x10^6$	$1.2x10^6$
			E	3.7	4.4	6.8	6.6	6.9	22	38.1	6.49	8.82	2.77	15	3.05	66.7	$6.0x10^4$	$1.2x10^4$
			R						89%	81%	22%	38%		83%	26%	18%		
May 8 - May 14	0.52	0.38	I		1.6	7.0	6.9	7.1	145	234	7.52	16.26	1.08	121	5.15	73.5	$6.5x10^6$	$1.1x10^6$
			E	5.9	3.4	6.8	6.7	6.9	30	59.5	7.98	10.49	0.56	19	3.68	71.2	$1.7x10^6$	$2.1x10^5$
			R						79%	74%		35%		84%	28%	3%		
May 15 - May 21	0.52	0.28	I		1.5	7.2	7.0	7.2	204	244	9.77	18.16	0.57	135	5.70	90.3	$6.4x10^6$	$1.0x10^6$
			E	4.7	3.5	6.9	6.8	7.1	19	48.8	9.22	11.94	0.18	15	4.70	88.2	$7.1x10^5$	$2.0x10^5$
			R						91%	80%	6%	34%		89%	18%	2%		
May 22 - May 28	0.48	0.26	I		2.2	7.4	7.2	7.6	222	264	13.13	18.90	0.31	131	5.03	98.7	$2.6x10^6$	$1.2x10^6$
			E	5.7	3.2	7.0	6.8	7.2	28	66.4	12.24	16.55	0.50	22	4.12	105	$2.6x10^6$	$4.2x10^5$
			R						87%	75%	7%	12%		83%	18%			
May 29 - Jun 4	0.76	0.72	I		2.0	7.1	6.9	7.3	178	373	15.82	24.77	0.11	132	6.20	103	$6.3x10^6$	$3.2x10^6$
			E	4.4	2.8	6.8	6.7	6.9	36	87.3	14.02	14.86	3.17	14	4.54	103	$5.6x10^5$	$5.5x10^5$
			R						80%	77%	11%	40%		89%	27%	0%		
Jun 5 - Jun 11	0.94	0.84	I		1.2	7.2	6.9	7.3	-	273	20.71	30.51	0.10	142	6.27	140	$3.5x10^6$	$2.6x10^6$
			E	5.1	2.2	6.8	6.7	7.0	-	49.7	18.66	19.24	0.62	19	5.15	131	$5.5x10^4$	$1.4x10^4$
			R							82%	10%	37%		87%	18%	6%		
Jun 12 - Jun 18	1.12	0.94	I		-	7.2	7.1	7.4	-	361	21.92	34.52	0.60	209	6.88	151	$1.5x10^7$	$3.8x10^6$
			E	5.0	-	6.8	6.7	6.8	-	114	16.59	21.06	5.03	26	6.10	109	$7.3x10^5$	$1.1x10^5$
			R							68%	24%	39%		88%	11%	28%		
June 19 - Jun 25			I		no analyses run													
			E															
			R															

APPENDIX B (CONTINUED)

																	Coliform - MF	
Period	Flow	Recycle	Sample	Turbidity	D.O.	pH	pH	pH	BOD$_5$	COD	NH$_3$-N	TKN	NO$_2$NO$_3$-N	TSS	Total P	Alk.	Total	Fecal
	MGD	MGD	Point*	NTU	mg/l	Med.	Min.	Max.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	#/100 ml	#/100 ml
1977 June 26-July 2	1.11		I		no analyses run													
			E															
			R															
July 3-July 9	1.05	0.54	I		0.3	7.1	7.0	7.2	---	509	23.89	34.62	---	464	6.14	143	1.4×10^7	5.0×10^6
			E	3.8	0.8	6.8	6.7	6.8	---	57.2	22.96	24.91	2.87	183	5.18	139	2.6×10^6	4.0×10^5
			R							89%	4%	28%		60%	16%	3%		
July 10-July 16	0.92	0.47	I		0.1	7.3	7.2	7.8	380	409	29.60	30.08	0.01	634	6.34	177	---	---
			E	4.1	1.1	7.0	7.0	7.1	32	69.9	27.11	30.34	0.47	45	5.74	163	2.3×10^6	3.9×10^5
			R						92%	83%		62%		93%	9%	8%		
July 17-July 23	0.98	0.45	I		0.1	7.2	7.1	7.4	368	526	26.58	41.28	0.02	280	6.45	160	2.2×10^7	8.9×10^6
			E	4.0	1.4	7.0	6.8	7.1	28	97.8	22.20	23.82	3.73	5.0	4.86	128	6.8×10^5	1.4×10^5
			R						92%	81%	16%	42%		98%	25%	20%		
July 24-July 30	1.02	0.41	I		0.0	7.3	7.1	7.4	305	399	22.70	37.22	0.38	210	5.76	154	7.2×10^6	3.5×10^6
			E	4.0	1.5	7.0	6.8	7.1	44	58.6	22.14	30.18	0.67	15	4.99	142	2.0×10^5	4.6×10^4
			R						86%	85%	2%	19%		93%	13%	8%		
July 31-August 6	1.12	0.41	I		0.0	7.4	7.3	8.0	260	350	26.99	39.63	---	162	9.32	168	---	---
			E	4.8	0.6	7.1	7.0	7.2	74	79.9	26.99	30.82	0.87	34	5.69	166	---	---
			R						72%	77%	0%	22%		79%	38%	1%		
Aug.7-Aug.13	0.93	0.40	I		0.0	7.3	7.2	7.5	349	480	25.47	38.53	0.02	188	7.72	161	---	---
			E	5.4	0.9	7.1	7.0	7.2		61.3	26.76	31.19	0.19	22	5.61	160	---	---
			R						92%	87%		19%		88%	27%	0%		
Aug.14-Aug.20	1.03	0.42	I		0.0	7.2	7.1	7.8	920	335	20.64	32.64	0.16	143	6.49	146	---	---
			E	8.2	0.8	6.9	6.8	7.1	355	86.2	18.70	23.78	3.05	34	5.38	126	---	---
			R						61%	74%	9%	27%		76%	17%	13%		
Aug.21-Aug.27	0.77	0.30	I		0.0	7.1	6.8	8.2	338	510	22.60	36.33	0.01	162	7.61	250	2.6×10^7	1.8×10^6
			E	4.4	1.3	6.8	6.6	7.0	74	74.7	21.32	27.11	2.11	30	4.44	132	7.4×10^5	3.2×10^4
			R						78%	85%	5%	25%		81%	41%	47%		
Aug.28-Sept.3	0.49	0.28	I		0.2	7.1	6.7	7.7	254	598	27.11	45.25	0.04	389	12.32	158	1.5×10^7	2.2×10^6
			E	3.3	2.1	6.7	5.8	7.0	42	57.7	24.78	27.20	4.86	28	6.67	135	1.2×10^5	2.5×10^4
			R						83%	90%	9%	40%		93%	46%	14%		

APPENDIX B (CONTINUED)

																	Coliform - MF	
Period	Flow	Recycle	Sample	Turbidity	D.O.	pH	pH	pH	BOD_5	COD	NH_3-N	TKN	NO_2NO_3-N	TSS	Total P	Alk.	Total	Fecal
	MGD	MGD	Point*	NTU	mg/l	Med.	Min.	Max.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	#/100 ml	#/100 ml
1977 Sept. 4-Sept. 10	0.54	0.21	I		0.1	7.1	6.8	7.2	195	512	16.15	29.24	0.18	278	6.08	127	$1.8x10^7$	$3.0x10^6$
			E	7.7	2.0	6.2	5.4	6.6	23	72.9	2.65	6.33	17.14	28	5.44	21.7	$1.6x10^5$	$1.9x10^4$
			R						88%	86%	84%	78%		90%	10%	83%		
Sept. 11-Sept. 17	0.56	0.22	I		0.2	7.0	6.7	7.9	262	294	11.31	20.68	0.04	244	7.44	105	$1.4x10^7$	$2.2x10^6$
			E	5.7	1.7	5.9	5.9	6.2	28	53.4	0.10	2.86	13.14	30	4.60	25.2	$3.9x10^4$	$1.2x10^3$
			R						89%	82%	99%	86%		88%	38%	76%		
Sept. 18-Sept. 24	0.58	0.23	I		0.1	7.1	7.0	7.6	318	361	15.02	24.73	-	162	5.47	133	$9.9x10^6$	$3.5x10^6$
			E	6.8	1.3	6.6	6.2	6.8	51	82.0	5.60	9.27	6.26	24	4.24	60.4	$2.4x10^4$	$4.5x10^3$
			R						84%	77%	63%	63%		85%	22%	54%		
Sept. 25-Oct. 1	0.49	0.30	I		0.5	7.1	6.7	7.6	250	441	22.80	34.56	0.01	294	9.29	152	$3.9x10^7$	$2.7x10^6$
			E	12	1.2	6.6	6.2	6.8	91	97.8	12.11	16.49	6.99	72	8.33	92.5	$4.0x10^5$	$1.0x10^4$
			R						64%	78%	47%	52%		76%	10%	39%		
Oct. 2-Oct. 8	0.40	0.28	I		0.5	7.0	6.7	7.1	250	325	12.55	22.49	0.02	104	6.73	117	$1.2x10^7$	$1.6x10^6$
			E	8.6	1.8	6.1	5.6	6.7	25	77.1	0.28	5.64	12.96	27	5.38	47.2	$2.2x10^5$	$1.0x10^4$
			R						90%	76%	98%	75%		74%	20%	60%		
Oct. 9-Oct. 15	0.40	0.27	I		0.8	7.0	6.9	7.1	-	240	11.81	24.72	1.03	145	9.06	124	$1.3x10^6$	$8.5x10^6$
			E	7.7	3.7	6.0	5.8	6.8	22	72.2	0.59	4.46	16.59	32	6.58	13.8	$1.3x10^3$	$1.0x10^3$
			R						-	70%	95%	82%		78%	27%	89%		
Oct. 16-Oct. 22	0.36	0.25	I		1.2	7.0	6.8	7.1	125	344	12.49	22.07	0.01	167	6.32	114	-	-
			E	5.7	3.2	5.7	5.4	6.6	20	53.8	0.04	2.92	17.60	21	5.02	5.7	-	-
			R						84%	84%	99%	87%		87%	20%	95%		
Oct. 23-Oct. 29	0.37	0.30	I		1.6	7.0	6.7	7.1	273	430	14.95	28.44	-	223	7.51	112	$1.2x10^7$	$1.4x10^6$
			E	17	3.0	5.6	5.6	5.4	44	80.0	0.07	4.39	18.33	36	5.48	6.2	$3.4x10^5$	$1.1x10^4$
			R						84%	81%	99%	84%		84%	27%	94%		
Oct. 30-Nov. 5	0.36	0.28	I		0.8	7.1	7.0	7.4	300	496	16.50	29.07	0.44	217	7.57	104	$1.0x10^7$	$1.6x10^6$
			E	10	3.5	5.8	5.3	6.6	31	79.7	0.24	4.35	14.75	26	5.42	15.7	$1.3x10^6$	$1.6x10^5$
			R						90%	84%	98%	85%		88%	28%	85%		
Nov. 6-Nov. 12	0.27	0.21	I		1.3	7.1	6.8	7.2	545	472	15.55	24.65	0.13	318	7.93	125	$1.7x10^6$	$3.9x10^5$
			E	7.9	3.8	5.5	5.2	5.6	33	60.6	0.07	3.46	20.30	30	6.59	4.3	$1.5x10^5$	$1.4x10^4$
			R						94%	87%	99%	86%		90%	17%	96%		

APPENDIX B (CONTINUED)

																	Coliform - MF	
Period	Flow	. Recycle	Sample	Turbidity	D.O.	pH	pH	pH	BOD_5	COD	NH_3-N	TKN	NO_2NO_3-N	TSS	Total P	Alk.	Total	Fecal
	MGD	MGD	Point*	NTU	mg/l	Med.	Min.	Max.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	#/100 ml	#/100 ml
1977 Nov.13-Nov.19	0.31	0.22	I		1.4	7.0	6.9	7.1	255	677	13.33	27.29	0.84	345	7.84	115	$6.3x10^6$	$2.2x10^6$
			E	16	4.8	6.2	5.8	6.3	26	111	0.41	5.11	16.34	51	8.65	19	$9.5x10^5$	$2.3x10^5$
			R						90%	84%	97%	81%		85%		83%		
Nov.20-Nov.26	0.32	0.30	I		1.7	6.9	6.8	7.1	230	570	13.62	27.10	0.03	188	7.30	114	$5.3x10^6$	$1.5x10^6$
			E	6.8	4.9	5.8	5.3	6.4	26	127	0.04	3.33	17.00	24	5.47	8.6	$3.2x10^5$	$3.0x10^4$
			R						89%	78%	100%	88%		87%	25%	92%		
Nov.27-Dec.3	0.30	0.25	I		2.8	7.0	6.9	7.1	290	407	14.61	28.39	0.26	249	6.72	114	$2.1x10^7$	$3.1x10^6$
			E	6.7	4.3	5.6	5.0	5.9	20	58.3	1.18	4.42	16.15	24	5.19	9.5	$2.4x10^5$	$4.4x10^3$
			R						93%	86%	92%	84%		90%	22%	92%		
Dec.4-Dec.10	0.32	0.25	I		2.0	7.1	7.0	7.1	153	529	15.05	25.33	0.16	233	5.93	43.5	$1.9x10^7$	$1.7x10^6$
			E	6.7	4.0	6.2	5.4	6.4	13	53.3	0.94	5.04	14.05	18	4.70	4.5	$4.4x10^5$	$5.1x10^4$
			R						91%	89%	93%	80%		92%	20%	89%		
Dec.11-Dec.17	0.31	0.23	I		2.3	7.3	7.2	7.4	264	364	15.16	27.98	1.07	222	6.72	66.1	$1.8x10^7$	$2.6x10^6$
			E	4.9	3.5	6.0	5.8	6.1	14	43.9	0.48	2.78	14.49	14	4.83	11.4	$6.0x10^3$	$\leq 1.0x10^3$
			R						94%	87%	96%	90%		93%	28%	82%		
Dec.18-Dec.24	0.29	0.21	I		0.8	7.3	7.2	7.4	50	272	16.96	26.37	0.01	202	6.79	135	$4.1x10^6$	$2.3x10^6$
			E	6.0	4.0	6.1	5.9	6.4	7.5	40.4	2.22	4.23	13.55	19	5.71	25.9	$1.4x10^4$	$1.9x10^3$
			R						85%	85%	86%	83%		90%	15%	80%		
Dec.25-Dec.31	0.48	0.28	I		0.6	7.6	7.0	8.0	207	430	28.66	38.36	7.68	231	11.54	167	$4.6x10^6$	$1.1x10^6$
			E	4.0	3.0	6.8	6.7	6.8	17	47.5	14.80	15.76	8.98	15	8.37	109	$2.0x10^6$	$1.4x10^5$
			R						91%	88%	48%	58%		93%	27%	34%		
1978 Jan.1-Jan.7	0.42	0.25	I		0.9	7.5	7.0	7.5	192	370	21.21	32.88	4.44	190	10.55	128	$4.9x10^6$	$1.7x10^6$
			E	4.2	3.7	6.8	6.7	6.8	20	54.2	15.24	19.48	4.05	14	8.92	102	$7.5x10^5$	$7.0x10^4$
			R						89%	85%	28%	41%		92%	15%	20%		
Jan.8-Jan.14	0.38	0.26	I		3.1	7.3	7.1	7.5	100	399	14.66	20.75	0.41	99	6.74	123	$9.0x10^6$	$2.2x10^6$
			E	4.8	4.8	6.8	6.7	6.9	11	49.1	12.11	12.95	3.32	13	4.82	101	$6.9x10^5$	$3.9x10^4$
			R						89%	87%	17%	37%		86%	28%	17%		
Jan.15-Jan.21	0.26	0.20	I		4.6	7.2	7.4	7.7	135	355	15.84	24.90	0.82	127	7.11	122	$1.1x10^7$	$2.4x10^6$
			E	4.3	4.8	6.8	6.7	6.8	10	32.0	14.90	17.37	1.75	18	5.03	107	$2.3x10^4$	$1.6x10^3$
			R						92%	90%	5%	30%		85%	29%	12%		

APPENDIX B (CONTINUED)

																	Coliform - MF	
Period	Flow	Recycle	Sample	Turbidity	D.O.	pH	pH	pH	BOD_5	COD	NH_3-N	TKN	NO_2NO_3-N	TSS	Total P	Alk.	Total	Fecal
	MGD	MGD	Point*	NTU	mg/l	Med.	Min.	Max.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	#/100 ml	#/100 ml
1978 Jan 22 - Jan 28	0.35	0.23	I		2.0	7.3	7.2	7.4	135	319	16.14	22.19	0.21	167	6.54	122	$6.1x10^6$	$2.4x10^6$
			E	6.3	4.7	6.8	6.	6.9	9.8	41.9	14.97	17.18	1.38	19	5.17	116	$5.7x10^4$	$8.9x10^3$
			R						93%	86%	7%	22%		89%	20%	4%		
Jan 29 - Feb 4	0.40	0.31	I		2.8	7.3	7.2	7.5	151	221	15.20	22.66	0.24	125	6.46	116	$5.4x10^6$	$1.6x10^6$
			E	6.8	5.2	6.9	6.8	7.2	17	56.9	14.98	16.92	1.39	21	5.00	106	$1.1x10^5$	$1.5x10^4$
			R						88%	74%	1%	25%		83%	22%	8%		
Feb 5 - Feb 11	0.37	0.30	I		2.7	7.2	7.1	7.3	150	399	16.62	25.97	0.12	153	8.82	126	$2.2x10^6$	$1.9x10^6$
			E	7.5	3.4	7.0	6.9	7.1	18	61.4	17.40	21.29	0.18	24	5.87	115	$8.2x10^5$	$2.6x10^5$
			R						88%	85%		18%		84%	33%	8%		
Feb 12 - Feb 18	0.44	0.30	I		3.6	7.4	6.9	7.5	134	276	13.80	22.32	0.16	116	6.54	85.5	$6.0x10^6$	$1.7x10^6$
			E	9.0	2.8	6.6	6.4	6.7	16	60.4	14.04	17.88	0.29	25	4.74	98.8	$3.2x10^5$	$3.0x10^4$
			R						88%	78%		19%		78%	27%			
Feb 19 - Feb 25	0.46	0.25	I		2.9	7.3	6.9	7.5	120	271	15.32	23.35	0.27	127	6.85	101	$4.7x10^6$	$2.0x10^6$
			E	7.1	1.9	6.7	6.6	6.7	18	52	15.79	18.59	0.06	23	5.47	97.1	$2.9x10^5$	$6.9x10^4$
			R						85%	81%		20%		82%	20%	4%		
Feb 26 - Mar 4	0.41	0.24	I		3.7	7.4	7.2	7.4	151	280	16.49	24.76	0.29	141	7.82	104	$5.7x10^6$	$6.0x10^5$
			E	4.6	2.1	6.6	6.6	6.7	14	39.3	15.26	18.12	0.03	17	5.25	106	$7.6x10^5$	$5.5x10^4$
			R						91%	86%	7%	27%		88%	33%			
Mar 5 - Mar 11	0.43	0.28	I		2.8	7.0	6.9	7.1	192	300	14.68	27.28	2.87	257	12.40	110	$3.8x10^6$	$2.2x10^6$
			E	4.2	2.3	6.6	6.4	6.9	12	56.0	15.12	18.18	0.10	15	14.20	113	$1.2x10^5$	$1.2x10^4$
			R						94%	81%		33%		94%				
Mar 12 - Mar 18	0.44	0.29	I		4.5	7.1	7.1	7.5	102	232	13.28	20.46	0.29	114	5.47	96.7	$5.3x10^6$	$1.4x10^6$
			E	3.2	2.4	6.6	6.5	6.7	9.2	38.6	12.88	15.11	0.20	13	4.70	92.8	$2.5x10^5$	$2.6x10^4$
			R						91%	83%	3%	26%		86%	14%	4%		
Mar 19 - Mar 25	0.54	0.34	I		1.9	7.3	6.7	7.5	319	470	16.90	25.57	0.39	214	6.35	108	$4.0x10^6$	$2.9x10^6$
			E	3.7	2.2	6.6	6.5	6.7	18	47.1	15.77	19.06	0.07	18	4.86	108		$1.5x10^6$
			R						94%	90%	7%	25%		92%	23%	0%		
Mar 26 - Apr 1	0.48	0.31	I		4.9	7.4	7.3	7.6	179	250		23.83	0.25	138	6.12		$4.4x10^6$	$2.7x10^6$
			E	4.7	3.0	6.6	6.3	6.8	12	61.9	13.33	16.93	0.59	14	4.22	105	$5.2x10^4$	$1.8x10^4$
			R						93%	75%		29%		90%	31%			

APPENDIX B (CONTINUED)

																	Coliform - MF	
Period	Flow	Recycle	Sample	Turbidity	D.O.	pH	pH	pH	BOD_5	COD	NH_3-N	TKN	NO_2NO_3-N	TSS	Total P	Alk.	Total	Fecal
	MGD	MGD	Point*	NTU	mg/l	Med.	Min.	Max.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	#/100 ml	#/100 ml
1978 April 2 - April 8	0.57	0.35	I		2.5	7.0	6.5	7.3	131	240	11.40	19.44	3.05	125	6.70	92.0	6.8x10^{6}	1.4x10^{6}
			E	4.3	2.9	6.6	6.4	6.7	9.3	62.1	12.00	14.82	0.47	16	6.10	98.0	6.2x10^{4}	2.1x10^{4}
			R						93%	74c		24%		87%	9%			
April 9 - April 15	0.50	0.33	I		2.4	6.8	7.0	7.1	188	275	10.63	16.60	0.64	142	4.78	75.6	9.0x10^{5}	2.8x10^{5}
			E	4.1	3.6	6.4	6.4	6.6	14	41.9	9.85	11.06	0.60	16	4.38	106	3.5x10^{4}	5.0x10^{3}
			R						92%	85%	6%	33%		89%	8%			
April 16-April 22	0.39	0.32	I		2.9	7.2	7.1	7.2	210	427	12.56	22.00	0.60	288	9.80	108	4.7x10^{6}	9.4x10^{5}
			E	5.2	3.8	6.6	6.6	6.7	14	51.5	13.47	15.50	0.76	13	6.18	112	4.2x10^{4}	1.5x10^{4}
			R						93%	88%		30%		95%	37%			
April 23-April 29	0.44	0.32	I		2.7	7.1	6.9	7.6	226	328	11.86	19.65	0.73	223	10.64	117	7.5x10^{6}	1.6x10^{6}
			E	5.9	3.4	6.6	6.6	6.7	14	60.7	12.79	14.85	1.27	20	7.08	116	9.3x10^{4}	2.9x10^{4}
			R						94%	81%		24%		91%	33%	1%		
April 30 - May 6	0.55	0.36	I		2.2	7.1	7.0	7.2	143	314	10.40	20.67	3.36	170	9.33	101	1.8x10^{6}	6.1x10^{5}
			E	5.7	3.4	6.6	6.5	7.0	6.9	54.6	11.11	13.45	2.49	18	8.82	80.8	1.8x10^{4}	3.9x10^{3}
			R						95%	83%		35%		89%	5%	20%		
May 7 - May 13	0.89	0.42	I		3.2	7.1	6.9	7.3	224	208	8.96	16.02	1.48	126	4.53	92.8	5.3x10^{6}	2.5x10^{6}
			E	6.4	3.6	6.7	6.6	6.8	20	43.6	9.03	11.59	1.48	14	3.07	95.6	1.2x10^{5}	3.9x10^{4}
			R						91%	79%		28%		88%	32%			
May 14 - May 20	1.10	0.45	I		2.8	7.1	7.0	7.2	156	293	6.84	17.75	0.78	210	7.48	97.7	4.0x10^{6}	2.0x10^{6}
			E	4.5	1.8	6.6	6.4	6.7	13	47.6	7.15	10.80	1.29	9.5	4.79	92.6	1.5x10^{4}	2.1x10^{3}
			R						92%	84%		39%		95%	36%	5%		
May 21 - May 27	0.92	0.38	I		2.9	7.2	7.1	7.3	112	194	9.17	16.14	1.81	-	4.13	101	-	-
			E	4.8	2.2	6.6	6.5	6.7	15	42.7	7.76	9.72	2.28	16	2.44	95.4	5.2x10^{4}	1.2x10^{4}
			R						87%	78%	15%	40%			41%	6%		
May 28 - June 3	0.73	0.39	I		2.9	7.1	7.0	7.5	164	273	14.51	20.50	0.91	157	5.69	132		
			E	5.6	2.8	6.6	6.5	6.8	21	58.5	13.37	17.02	1.54	20	3.64	121		
			R						87%	79%	8%	17%		87%	36%	8%		
June 4 - June 10	0.74	0.39	I		1.5	7.2	7.0	7.3	345	349	15.49	22.93	1.77	202	-	114		
			E	6.2	2.4	6.6	6.6	6.7	45	60.8	14.43	16.72	3.80	16	-	120		
			R						87%	83%	7%	27%		92%				

APPENDIX B (CONTINUED)

																	Coliform - MF	
Period	Flow	Recycle	Sample	Turbidity	D.O.	pH	pH	pH	BOD_5	COD	NH_3-N	TKN	NO_2NO_3-N	TSS	Total P	Alk.	Total	Fecal
	MGD	MGD	Point*	NTU	mg/1	Med.	Min.	Max.	mg/1	mg/1	mg/1	mg/1	mg/1	mg/1	mg/1	mg/1	#/100 ml	#/100 ml
1978 June 11-17	0.92	0.48	I		0.83	7.3	7.0	7.6	272		15.31		0.62	196		130		
			E	5.8	2.2	6.8	6.5	7.7			13.73	17.38	2.09	24		116		
			R								10%			88%		11%		
June 18-24	0.76	0.41	I		1.6	7.1	6.9	7.6	171		19.48		2.93			141		
			E	6.0	2.2	6.7	6.5	6.9			18.29	23.46	4.69			123		
			R								7%					13%		
June 25-July 1	0.76	0.40	I		0.2	7.1	7.1	7.2	343		22.52		0.47	293		147		
			E	6.3	1.1	6.7	6.4	6.8			21.87	21.63	1.97			139		
			R								3%					5%		
July 2 - 8	0.70	0.43	I						422		29.66		0.14	256				
			E	7.0	1.3	6.8	6.6	7.0	37		21.99	28.39	1.73	18		158		
			R						91%		26%			93%				
July 9-15	0.70	0.48	I						322		29.96		0.17	198				
			E	5.6	1.9	6.7	6.6	6.7	67		17.53	17.96	10.38	23		106		
			R						80%		41%			88%				
July 16-22	0.74	0.51	I						445		38.30		0.35	254		220		
			E	3.8	2.0						24.11	28.49	8.98			108		
			R								37%					51%		
July 23-29	0.76	0.50	I						535		33.54		0.03	486		184		
			E	6.9	2.9	6.8	6.7	6.9			21.84	24.98	6.94			109		
			R								35%					41%		
			I															
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APPENDIX C

SUMMARY OF LABORATORY DATA - NITRIFICATION TOWER, DUMPED MEDIA

																	Coliform - MF	
Period	Flow	Recycle	Sample	Temp.**	D.O.	pH	pH	pH	BOD$_5$	COD	NH$_3$-N	TKN	NO$_2$NO$_3$-N	TSS	Total P	Alk.	Total	Fecal
	MGD	MGD	Point*	°C	mg/l	Med.	Min.	Max.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	#/100 ml	#/100 ml
1976			I															
			E															
			R															
Jul 11 - Jul 17	0.78	0.00	I		1.4	6.5	6.0	6.9	56	119	8.60	16.70	5.30	51	5.27			
			E		4.6	7.5	6.7	7.5	34	85.0	6.36	15.00	5.47	45	3.79			
			R						38%	29%	26%	10%		11%	28%			
Jul 18 - Jul 24	0.56	0.00	I		1.6	6.1	5.8	6.4	80	178	6.40	13.90	1.50	-	8.60			
			E		6.4	6.8	6.6	7.4	110	200	7.30	11.10	15.00	-	9.00			
			R									20%						
Jul 25 - Jul 31	0.58	1.16	I	18	1.8	6.7	6.2	7.3	62	132	3.60	10.50	0.12	-				
			E	18	6.0	7.2	7.0	7.9	49	125	3.20	11.30	12.20	-				
			R						21%	5%	11%							
Aug 8 - Aug 14	0.15	0.00	I	17	2.3	5.7	5.3	6.6	24	70.0	5.15	8.30	-	26				
			E	17	3.8	7.4	7.4	7.5	36	59.0	4.90	6.25	29.40	5.5				
			R							16%	5%	25%		79%				
Aug 15 - Aug 21	0.30	0.00	I	18	2.4	5.5	5.2	7.0	54	92.0	2.25	9.60	21.40	47				
			E	17	4.1	5.9	5.4	7.5	52	91.0	-	-	23.05	40				
			R						4%	1%				14%				
Aug 22 - Aug 28	0.54	1.34	I	17	2.9	6.0	5.6	7.7	44	74.0	3.40	7.80	21.70	46				
			E	17	3.6	6.4	6.1	7.3	44	66.5	2.98	6.65	23.17	35				
			R						0%	10%	12%	15%		25%				
Aug 29 - Sept 4	0.38	1.57	I	17	2.9	6.2	6.0	6.5	37	65.3	2.20	5.40	16.50	22				
			E	17	2.9	6.3	5.9	6.4	17	69.3	0.60	2.67	19.95	14				
			R						54%		73%	51%		37%				
Sept 5 - Sept 11	0.48	1.68	I	16	2.7	5.8	5.4	6.2	-	-	-	-	-	-				
			E	17	4.4	6.0	5.7	6.5	-	-	-	-	-	-				
			R															
Sept 12 - Sept 18	0.38	1.61	I	16	2.3	5.8	5.5	6.0	-	49.5	2.10	13.80	11.90	11				
			E	16	4.6	6.5	6.2	6.8	-	91.0	-	3.40	13.60	15				
			R									75%		-27%				

* I = Flow from Activated Sludge Process E = Effluent from Dumped Media Nitrification Tower
R = Percent removal where applicable

** I = Influent temperature ** E = Effluent temperature
R = Ambient Air Temperature Maximum/Ambient Air Temperature Minimum

APPENDIX C (CONTINUED)

																	Coliform - MF	
Period	Flow	Recycle	Sample	Temp.**	D.O.	pH	pH	pH	BOD_5	COD	NH_3-N	TKN	NO_2NO_3-N	TSS	Total P	Alk.	Total	Fecal
	MGD	MGD	Point*	°C	mg/l	Med.	Min.	Max.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	#/100 ml	#/100 ml
1976 Sept 19 - Sept 25	0.54	1.63	I	16	3.1	5.9	5.7	6.0	65	-	-	12.60	12.44	14	-	11.7		
			E	16	4.0	6.3	5.8	6.8	55	-	-	13.20	9.90	10	-	4.9		
			R						16%			5%		71%		58%		
Sept 26 - Oct 2	0.48	1.68•	I	15	3.5	5.7	5.0	6.2	-	-	-	-	11.50	7.0	-	-		
			E	14	5.2	6.6	5.5	6.9	-	-	-	-	11.30	5.1	-	-		
			R											27%				
Oct 3 - Oct 9	0.40	1.59	I	15	3.1	5.8	4.7	5.9	39	51.9	-	7.60	12.20	18	-	-		
			E	14	5.0	6.3	5.0	6.9	23	37.7	-	2.10	12.20	9.5	-	-		
			R						41%	27%		72%		48%				
Oct 10 - Oct 16	0.26	1.42	I	14	4.5	6.2	5.9	6.8	22	48.2	0.28	3.60	9.85	42	5.40	26.4	5.2×10^{4}	3.8×10^{4}
			E	13	6.1	6.8	6.4	7.3	13	36.1	0.14	1.90	7.81	30	5.17	26.4	7.2×10^{4}	9.3×10^{3}
			R						41%	25%	50%	47%		30%	4%	0%		
Oct 17 - Oct 23	0.22	1.16	I	13	4.2	5.7	5.5	6.0	32	60.0	-	3.55	14.11	34	2.30	31.3	2.0×10^{5}	6.6×10^{3}
			E	12	7.3	5.8	6.3	6.6	21	57.2	-	2.85	14.07	27	2.40	25.5	1.0×10^{5}	1.9×10^{3}
			R						35%	5%		20%		21%	4%	19%		
Oct 24 - Oct 30	0.18	1.27	I	12	5.5	5.7	5.3	6.3	24	58.6	0.33	5.10	14.39	33	1.90	19.4	3.5×10^{5}	5.8×10^{3}
			E	12	7.3	6.2	5.8	6.4	24	50.8	0.11	2.92	13.93	28	1.80	15.4	1.2×10^{5}	6.8×10^{3}
			R						0%	13%	67%	43%		13%	5%	21%		
Oct 31 - Nov 6	0.23	1.29	I	12	5.5	5.8	5.7	6.5	22	58.8	0.98	4.10	21.18	26	3.98	27.0	1.5×10^{5}	7.6×10^{3}
			E	12	7.4	6.6	6.2	6.8	15	56.6	0.53	3.47	19.27	17	3.98	28.0	1.1×10^{5}	6.0×10^{3}
			R						31%	4%	46%	15%		35%	0%			
Nov 7 - Nov 13	0.21	1.33	I	11	4.0	5.9	5.8	6.2	21	73.4	1.68	3.73	11.96	26	3.59	30.0	3.7×10^{5}	1.0×10^{5}
			E	10	8.0	6.5	6.4	6.6	19	67.2	0.08	2.61	12.30	23	3.36	26.3	1.7×10^{5}	4.7×10^{3}
			R						11%	8%	95%	30%		12%	6%	17%		
Nov 14 - Nov 20	0.28	1.49	I	10	4.7	6.3	5.6	6.9	40	56.1	1.94	4.84	8.49	32	3.51	38.3	4.4×10^{5}	5.0×10^{4}
			E	9	7.6	6.9	6.5	7.6	26	47.8	-	3.73	8.89	24	3.40	31.7	1.4×10^{5}	1.3×10^{4}
			R						35%	15%		22%		26%	3%	17%		
Nov 21 - Nov 27	0.20	1.32	I	9	3.5	6.6	6.5	7.3	-	62.1	5.60	5.80	5.50	35	2.80	59.0	3.6×10^{5}	4.3×10^{5}
			E	9	6.6	7.2	7.0	7.7	34	55.3	1.20	3.70	7.90	30	2.60	42.7	2.4×10^{5}	7.3×10^{4}
			R							11%	79%	36%		14%	7%	28%		

APPENDIX C (CONTINUED)

																	Coliform - MF	
Period	**Flow**	**Recycle**	**Sample**	**Temp.****	**D.O.**	**pH**	**pH**	**pH**	**BOD_5**	**COD**	**NH_3-N**	**TKN**	**NO_2NO_3-N**	**TSS**	**Total P**	**Alk.**	**Total**	**Fecal**
	MGD	**MGD**	**Point***	**°C**	**mg/l**	**Med.**	**Min.**	**Max.**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**#/100 ml**	**#/100 ml**
1976 Nov 28 - Dec 4	0.36	1.00	I	7	3.7	6.6	6.6	7.0	26	17.0	4.38	5.16	2.44	17	3.17	56.5	$2.0x10^5$	$9.0x10^4$
			E	6	7.4	7.1	6.9	7.2	16	15.0	1.00	3.76	6.57	13	2.55	33.3	$1.0x10^5$	$4.0x10^4$
			R						36%	12%	77%	27%		21%	20%	41%		
Dec 5 - Dec 11	0.25	0.68	I	7	4.7	6.6	6.5	6.9	32	29.0	3.88	6.02	4.27	20	2.83	52.5	$7.3x10^4$	3.7x103
			E	6	7.8	7.2	6.9	7.6	20	34.5	0.78	3.30	6.95	17	2.98	30.0	$5.2x10^4$	$2.0x10^3$
			R						37%		80%	45%		11%		43%		
Dec 12 - Dec 18	0.21	0.39	I	7	3.5	6.5	6.4	6.6	37	39.3	4.00	4.70	5.20	16	2.58	46.9	$9.2x10^4$	$7.1x10^3$
			E	7	8.2	7.0	6.7	7.1	24	29.1	1.70	2.86	10.21	9.6	2.46	33.2	$4.0x10^4$	$3.0x10^3$
			R						36%	26%	58%	39%		40%	5%	29%		
Dec 19 - Dec 25	0.26	0.47	I	6	4.0	6.6	6.2	6.8	26	43.8	5.93	6.58	0.73	15	2.84	55.4	$1.2x10^5$	$3.2x10^4$
			E	6	7.6	7.0	6.5	7.3	20	36.0	3.72	5.36	3.63	11	2.72	47.8	$7.6x10^4$	$1.5x10^4$
			R						25%	18%	37%	19%		25%	4%	14%		
Dec 26 - Jan 1	0.37	0.54	I	6	2.8	6.8	6.7	6.9	33	46.4	13.09	9.95	0.84	16	3.15	77.6	$5.1x10^5$	$5.9x10^4$
			E	5	8.3	7.3	7.1	7.4	32	38.6	8.61	8.91	2.38	14	3.09	57.0	$4.7x10^5$	$5.4x10^4$
			R						4%	17%	34%	10%		11%	2%	27%		
1977 Jan 2 - Jan 8	0.30	0.51	I	6	4.5	6.8	6.8	6.9	30	48.8	6.00	8.94	6.36	14	4.13	65.6	$2.4x10^5$	$5.3x10^4$
			E	5	8.0	7.2	7.0	7.3	22	38.9	3.93	6.09	8.67	10	3.93	47.7	$2.1x10^5$	$4.2x10^4$
			R						24%	20%	35%	32%		27%	7%	27%		
Jan 9 - Jan 15	0.45	0.65	I	6	5.6	6.8	6.8	7.2	31	42.4	5.89	7.00	5.17	20	3.25	67.9	$8.0x10^4$	$2.4x10^4$
			E	5	8.8	7.4	7.2	7.5	25	35.3	4.28	5.78	4.66	13	3.17	52.8	$5.1x10^4$	$1.7x10^4$
			R						19%	17%	27%	17%		35%	2%	22%		
Jan 16 - Jan 22	0.62	0.70	I	6	5.0	6.9	6.8	7.0	18	36.5	5.63	7.41	1.22	11	2.62	61.3	$1.2x10^5$	$3.3x10^4$
			E	6	9.4	7.2	7.0	7.4	17	35.5	3.96	5.83	3.46	14	2.64	46.4	$1.4x10^5$	$6.9x10^4$
			R						3%	3%	30%	21%				24%		
Jan 23 - Jan 29	0.50	0.00	I	7	4.0	7.2	6.8	7.8	38	52.7	6.58	7.93	0.97	27	3.07	61.8	$2.6x10^5$	$8.2x10^4$
			E	6	9.1	7.4	7.2	7.7	34	49.2	4.79	6.19	3.05	13	2.92	55.9	$2.4x10^5$	$1.7x10^5$
			R						10%	7%	27%	22%		51%	5%	10%		
Jan 30 - Feb 5	0.47	0.00	I	6	3.1	7.0	6.8	7.3	23	42.5	7.65	10.47	0.86	16	3.15	71.2	$9.2x10^4$	$1.4x10^4$
			E	5	8.0	7.1	7.1	7.2	18	41.5	6.10	8.19	2.41	14	3.06	63.7	$1.8x10^5$	$4.1x10^4$
			R						22%	2%	20%	22%		13%	3%	11%		

APPENDIX C (CONTINUED)

																	Coliform - MF	
Period	Flow MGD	Recycle MGD	Sample Point*	Temp.** °C	D.O. mg/l	pH Med.	pH Min.	pH Max.	BOD_5 mg/l	COD mg/l	NH_3-N mg/l	TKN mg/l	NO_2NO_3-N mg/l	TSS mg/l	Total P mg/l	Alk. mg/l	Total #/100 ml	Fecal #/100 ml
1977 Feb 6 - Feb 12	0.45	0.00	I	7	3.5	6.9	6.8	7.1	21	48.8	7.44	9.86	1.97	33	2.39	69.7	1.0×10^5	3.6×10^4
			E	4	7.2	7.2	7.1	7.4	21	42.1	6.00	8.32	2.08	34	2.29	64.4	1.5×10^5	9.3×10^4
			R						0%	14%	19%	16%			4%	8%		
Feb 13 - Feb 19	0.48	0.00	I	6	4.3	6.9	6.8	7.5	38	40.0	7.36	9.71	0.39	16	2.63	73.0	1.0×10^5	4.5×10^4
			E	4	7.5	7.2	6.9	7.5	24	34.0	6.14	8.48	1.56	10	2.51	79.5	1.4×10^5	6.5×10^4
			R	6/11					37%	15%	17%	13%		32%	5%			
Feb 20 - Feb 26	0.48	0.00	I	5	3.9	6.9	6.7	6.9	14	46.4	6.61	11.25	0.98	17	3.03	73.6	5.2×10^5	3.3×10^4
			E	4	7.2	7.2	7.1	7.4	12	42.0	5.66	7.66	1.86	12	3.00	65.1	1.0×10^5	3.7×10^4
			R	4/-8					17%	9%	14%	32%		26%	1%			
Feb 27 - Mar 5	0.48	0.00	I	5	4.9	6.9	6.7	7.0	26	48.6	7.06	10.07	0.74	22	2.99	74.8	5.0×10^4	5.5×10^3
			E	4	7.5	7.2	7.0	7.6	14	38.9	5.68	8.67	1.92	15	2.89	65.6	5.1×10^4	9.9×10^3
			R	-1/-14					44%	20%	20%	14%		31%	3%	12%		
Mar 6 - Mar 12	0.48	0.00	I	6	5.4	6.7	6.7	6.8	19	51.5	7.24	9.75	2.95	16	3.98	74.5	9.2×10^4	9.2×10^3
			E	4	8.2	7.2	7.1	7.3	16	35.5	5.99	10.07	4.50	13	3.92	64.8	1.1×10^5	1.0×10^4
			R	8/-8					16%	31%	17%			19%	2%	13%		
Mar 13 - Mar 19	0.48	0.30	I	5	5.3	6.7	6.7	6.8	38	51.0	6.89	10.14	1.69	24	4.64	70.0	7.2×10^4	1.3×10^4
			E	4	8.0	7.2	7.1	7.2	28	45.5	5.59	8.84	3.59	20	4.62	58.1	5.5×10^4	1.0×10^4
			R	8/-10					26%	11%	19%	13%		17%	0%	17%		
Mar 20 - Mar 26	0.40	0.67	I	5	5.1	6.8	6.7	6.9	26	56.5	7.04	10.04	1.44	21	3.01	74.5	7.9×10^5	1.1×10^4
			E	5	7.8	7.0	6.9	7.9	21	60.0	4.83	7.70	3.95	18	2.98	59.6	6.0×10^4	8.0×10^3
			R	7/-6					19%		31%	23%		15%	1%	20%		
Mar 27 - Apr 2	0.48	0.53	I	6	5.0	6.8	6.7	7.1	26	51.0	6.90	10.44	2.35	19	3.04	76.0	6.7×10^5	1.8×10^5
			E	5	6.5	7.2	7.0	8.6	41	51.2	4.35	7.70	5.27	21	3.16	58.3	5.6×10^5	8.9×10^4
			R	6/-10						0%	37%	26%				23%		
Apr 3 - Apr 9	0.48	0.66	I	8	4.2	6.9	6.8	7.0	30	50.1	8.88	10.46	2.47	16	3.26	72.7	6.7×10^5	9.7×10^4
			E	7	7.2	7.3	7.2	7.4	21	33.8	5.29	7.67	5.27	9.8	3.26	54.6	6.0×10^5	2.2×10^5
			R	10/-7					30%	32%	40%	27%		39%	0%	25%		
Apr 10 - Apr 16	0.34	0.56	I	9	4.4	6.8	6.7	7.4	21	54.6	6.08	10.64	1.53	23	3.15	78.8	6.5×10^5	1.3×10^5
			E	7	7.3	7.2	7.0	7.4	21	47.9	3.90	5.90	5.80	13	3.17	56.6	4.9×10^5	4.5×10^4
			R	13/-3					0%	12%	36%	44%		43%		28%		

APPENDIX C (CONTINUED)

																	Coliform - MF	
Period	Flow	Recycle	Sample	Temp.**	D.O.	pH	pH	pH	BOD_5	COD	NH_3-N	TKN	NO_2NO_3-N	TSS	Total P	Alk.	Total	Fecal
	MGD	MGD	Point*	°C	mg/l	Med.	Min.	Max.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	#/100 ml	#/100 ml
1977 Apr 17 - Apr 23	0.42	0.67	I	8	4.4	6.7	6.5	6.9	40	55.2	7.62	10.82	1.25	19	3.53	96.8	$9.6x10^5$	$3.2x10^5$
			E	7	8.1	7.2	7.0	7.4	32	67.0	3.67	7.43	5.56	15	3.48	57.2	$8.0x10^5$	$2.3x10^5$
			R	11/-4					20%	21%	52%	31%		21%	1%	41%		
Apr 24 - Apr 30	0.66	0.64	I	9	4.9	6.6	6.7	6.8	20	63.1	7.19	9.78	1.84	15	5.59	75.6	$3.7x10^5$	$3.8x10^4$
			E	9	7.1	7.0	6.9	7.1	30	62.4	2.53	5.31	6.82	12	5.59	39.9	$3.0x10^5$	$4.9x10^4$
			R	15/3						1%	65%	46%		20%	0%	47%		
May 1 - May 7	0.42	0.66	I	9	4.4	6.8	6.6	6.9	22	38.1	6.49	8.82	2.77	15	3.05	66.7	$6.0x10^4$	$1.2x10^4$
			E	8	7.3	7.0	7.0	7.2	24	35.8	1.13	4.50	8.57	15	3.03	25.6	$2.9x10^4$	$9.5x10^3$
			R	15/0						6%	82%	49%		0%	1%	62%		
May 8 - May 14	0.52	0.63	I	10	3.4	6.8	6.7	6.9	30	59.5	7.98	10.49	0.56	19	3.68	71.2	$1.7x10^6$	$2.1x10^5$
			E	10	6.3	6.9	6.8	7.1	28	54.3	1.33	4.31	7.59	26	3.83	36.8	$8.9x10^5$	$1.9x10^5$
			R	18/1					7%	9%	83%	59%				48%		
May 15 - May 21	0.52	0.63	I	10	3.5	6.9	6.8	7.1	19	48.8	9.22	11.94	0.18	15	4.70	88.2	$7.1x10^5$	$2.0x10^5$
			E	10	5.6	6.8	6.7	6.9	27	62.9	1.31	4.39	7.40	14	4.80	28.0	$4.7x10^5$	$7.0x10^4$
			R	16/-3							86%	63%		7%		68%		
May 22 - May 28	0.48	0.53	I	11	3.2	7.0	6.8	7.2	28	66.4	12.24	16.55	0.50	22	4.12	106	$2.6x10^6$	$4.2x10^5$
			E	10	5.4	6.9	6.7	7.5	17	68.0	3.63	6.57	10.90	19	4.18	32.7	$1.9x10^6$	$3.6x10^5$
			R	17/2					39%	2%	70%	60%		14%		69%		
May 29 - June 4	0.76	0.57	I	12	2.8	6.8	6.7	6.9	36	87.3	14.02	14.86	3.17	14	4.54	103	$5.6x10^5$	$5.5x10^5$
			E	12	5.1	6.8	6.7	6.9	32	78.5	5.78	7.76	10.16	14	4.69	47.0	$3.4x10^5$	$2.8x10^5$
			R	21/2					11%	10%	59%	48%		0%		54%		
Jun 5 - Jun 11	0.94	0.00	I	14	2.2	6.8	6.7	7.0	-	49.7	18.66	19.24	0.62	19	5.15	131	$5.5x10^4$	$1.4x10^4$
			E	13	4.4	6.8	6.8	6.9	-	41.7	7.77	12.05	10.50	19	5.20	44.9	$3.0x10^4$	$1.0x10^4$
			R	24/6						16%	58%	37%		0%		66%		
Jun 12 - Jun 18	1.12	0.46	I	16	-	6.8	6.7	6.8	-	114	16.59	21.06	5.03	26	6.10	109	$7.3x10^5$	$1.1x10^5$
			E	15	-	6.6	6.5	7.2	-	64.9	8.92	12.18	14.05	27	6.18	37.4	$2.3x10^5$	$5.5x10^4$
			R	23/5						43%	46%	42%				66%		
Jun 19 - Jun 25			I															
			E		no analyses run													
			R															

APPENDIX C (CONTINUED)

Period	Flow MGD	Recycle MGD	Sample Point*	Temp.** °C	D.O. mg/l	pH Med.	pH Min.	pH Max.	BOD$_5$ mg/l	COD mg/l	NH$_3$-N mg/l	TKN mg/l	NO$_2$NO$_3$-N mg/l	TSS mg/l	Total P mg/l	Alk. mg/l	Coliform - MF Total #/100 ml	Coliform - MF Fecal #/100 ml
1977 June 26-July 2	1.11	0.62	I		no analyses run													
			E															
			R															
July 3-July 9	1.05	0.25	I	18	0.8	6.8	6.7	6.8	---	57.2	22.96	24.91	2.87	183	5.18	139	$2.6x10^{6}$	$4.0x10^{5}$
			E	17	3.6	7.1	6.9	7.1	---	59.1	15.07	20.54	10.85	184	5.22	90.7	$2.3x10^{5}$	$2.0x10^{4}$
			R	25/7							34%	18%		0%		35%		
July 10-July 16	0.92	0.33	I	18	1.1	7.0	7.0	7.1	32	69.9	27.11	30.34	0.47	45	5.74	163	$2.3x10^{6}$	$3.9x10^{5}$
			E	17	3.9	7.3	7.2	7.4	102	73.8	19.29	22.87	11.22	51	5.74	96.8	---	---
			R	25/4							29%	25%			0%	41%		
July 17-July 23	0.98	0.38	I	19	1.4	7.0	6.8	7.1	28	97.8	22.20	23.82	3.73	5.0	4.86	128	$6.8x10^{5}$	$1.4x10^{5}$
			E	18	2.1	7.1	7.0	7.1	125	64.7	11.53	14.89	13.22	11	5.00	62.0	$4.5x10^{5}$	$5.1x10^{4}$
			R	23/9						34%	48%	38%				52%		
July 24-July 30	1.02	0.38	I	19	1.5	7.0	6.8	7.1	44	58.6	22.14	30.18	0.67	15	4.99	142	$2.0x10^{5}$	$4.6x10^{4}$
			E	21	3.3	7.2	7.0	7.3	88	96.3	13.28	17.26	9.31	46	5.44	78.0	$1.6x10^{5}$	$3.8x10^{4}$
			R	19/8							40%	43%				45%		
July 31-Aug.6	1.12	0.31	I	18	0.6	7.1	7.0	7.2	74	79.9	26.99	30.82	0.87	34	5.69	166	---	---
			E	18	2.3	7.2	7.0	7.4	107	200	18.53	30.69	11.66	104	7.66	104	---	---
			R	23/7							31%	0%				37%		
Aug.7-Aug.13	0.93	0.74	I	18	0.9	7.1	7.0	7.2		61.3	26.76	31.19	0.19	22	5.61	160	---	---
			E	18	3.3	7.1	7.0	7.2	99	79.2	16.69	21.63	13.40	22	5.85	83.8	---	---
			R	24/5							37%	30%		0%		47%		
Aug.14-Aug.20	1.03	0.53	I	18	0.8	6.9	6.8	7.1	355	86.2	18.70	23.78	3.05	34	5.38	126	---	---
			E	18	3.5	7.1	6.9	7.2	290	89.7	10.53	15.61	14.00	37	5.47	64.1	---	---
			R	23/5					18%		43%	34%				49%		
Aug.21-Aug.27	0.77	0.65	I	18	1.3	6.8	6.6	7.0	74	74.7	21.32	27.11	2.11	30	4.44	132	$7.4x10^{5}$	$3.2x10^{4}$
			E	18	3.8	6.8	6.5	7.0	74	78.6	10.60	15.91	24.19	34	4.69	67.0	$3.5x10^{4}$	$1.7x10^{3}$
			R	24/6					0%		50%	41%				49%		
Aug.28-Sept.3	0.49	0.92	I	17	2.1	6.7	5.8	7.0	42	57.7	24.78	27.20	4.86	28	6.67	135	$1.2x10^{5}$	$2.5x10^{4}$
			E	17	4.9	6.0	5.3	6.9	62	63.0	9.24	12.68	21.63	23	6.72	23.3	$3.5x10^{4}$	$6.0x10^{2}$
			R	24/6							63%	53%		18		83%		

APPENDIX C (CONTINUED)

																	Coliform - MF	
Period	Flow	Recycle	Sample	Temp.**	D.O.	pH	pH	pH	BOD$_5$	COD	NH$_3$-N	TKN	NO$_2$NO$_3$-N	TSS	Total P	Alk.	Total	Fecal
	MGD	MGD	Point*	°C	mg/1	Med.	Min.	Max.	mg/1	mg/1	mg/1	mg/1	mg/1	mg/1	mg/1	mg/1	#/100 ml	#/100 ml
1977 Sept.4-Sept.10	0.54	0.93	I	16	2.0	6.2	5.4	6.6	23	72.9	2.65	6.33	17.14	28	5.44	21.7	$1.6x10^5$	$1.9x10^4$
			E	16	6.2	6.3	6.1	6.8	11	50.7	0.65	3.69	20.91	22	5.44	11.4	$6.6x10^4$	$2.6x10^3$
			R	24/7					52%	30%	75%	42%		21%	0	47%		
Sept.11-Sept.17	0.56	1.04	I	16	1.7	5.9	5.9	6.2	28	53.4	0.10	2.86	13.14	30	4.60	25.2	$3.9x10^4$	$1.2x10^3$
			E	16	6.5	6.8	6.4	6.9	20	49.5	0.13	2.54	13.15	28	4.66	25.9	$4.6x10^4$	$2.4x10^2$
			R	19/0					28%	7%		11%		6%		3%		
Sept.18-Sept.24	0.58	0.88	I	16	1.3	6.6	6.2	6.8	51	82.0	5.60	9.27	6.26	24	4.24	60.4	$2.4x10^4$	$4.5x10^3$
			E	15	6.1	6.9	6.6	7.2	43	65.4	3.60	6.50	11.92	24	4.10	30.4	$3.8x10^4$	$1.2x10^3$
			R	17/2					16%	20%	36%	30%		0	3%	50%		
Sept.25-Oct.1			I	Switch Over to Redwood Media														
			E															
			R															
			I															
			E															
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APPENDIX D

SUMMARY OF LABORATORY DATA - NITRIFICATION TOWER, REDWOOD MEDIA

Period	Flow	Recycle	Sample	Temp.**	D.O.	pH	pH	pH	BOD$_5$	COD	NH$_3$-N	TKN	NO$_2$NO$_3$-N	TSS	Total P	Alk.	Coliform - MF	
	MGD	MGD	Point*	°C	mg/l	Med.	Min.	Max.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	Total #/100 ml	Fecal #/100 ml
1977 Sept. 4-Sept. 10			I															
			E															
			R															
Sept. 11-Sept 17			I															
			E															
			R															
Sept. 18-Sept. 24			I															
			E															
			R															
Sept. 25-Oct. 1	0.49	0.82	I	16	1.2	6.6	6.2	6.8	91	97.8	12.11	16.49	6.99	72	8.33	92.5	$4.0x10^5$	$1.0x10^4$
			E	15	6.0	7.2	6.8	7.4	82	113	9.38	13.61	11.43	69	8.27	62.0	$1.6x10^5$	$1.5x10^4$
			R	18/-2					9%	13%	22%	17%		4%	1%	33%		
Oct. 2-Oct. 8	0.40	0.00	I	15	1.8	6.1	5.6	6.7	25	77.1	0.28	5.64	12.96	27	5.38	47.2	$2.2x10^5$	$1.0x10^4$
			E	14	6.7	6.8	6.2	7.0	31	68.1	0.38	5.82	12.88	29	5.61	29.2	$1.9x10^4$	$1.0x10^4$
			R	11/-6						12%	36%				4%	38%		
Oct. 9-Oct. 15	0.40	0.75	I	14	3.7	6.0	5.8	6.8	22	72.2	0.59	4.46	16.59	32	6.58	13.8	$1.3x10^3$	$1.0x10^3$
			E	14	6.9	6.8	6.3	6.9	28	75.4	0.63	6.37	16.18	33	7.10	13.8	$1.0x10^4$	$8.4x10^2$
			R	16/-8						4%		43%				0%		
Oct. 16-Oct. 22	0.36	1.14	I	13	3.2	5.7	5.4	6.6	20	53.8	0.04	2.92	17.60	21	5.02	5.7	-	-
			E	12	7.2	6.5	6.2	6.7	20	47.4	0.03	2.53	16.67	24	5.05	7.0	-	-
			R	17/-5					0%	12%	25%	13%						
Oct. 23-Oct. 29	0.37	0.96	I	12	3.0	5.6	5.6	5.4	44	80.0	0.07	4.39	18.33	36	5.48	6.2	$3.4x10^5$	$1.1x10^4$
			E	11	7.6	6.4	6.0	6.7	30	68.8	0.05	3.98	17.95	34	5.48	7.8	$1.1x10^5$	$4.6x10^3$
			R	15/-4					32%	14%	28%	9%		5%	0%			
Oct. 30-Nov. 5	0.36	1.01	I	11	3.5	5.8	5.3	6.6	31	79.7	0.24	4.35	14.75	26	5.42	15.7	$1.3x10^6$	$1.6x10^5$
			E	10	7.6	6.8	5.7	6.9	30	71.0	<0.01	4.28	15.08	29	5.48	17.7	$6.7x10^5$	$4.5x10^4$
			R	11/-2					3%	11%	≥96%	1%						
Nov. 6-Nov. 12	0.27	1.17	I	10	3.8	5.5	5.2	5.6	33	60.6	0.07	3.46	20.30	30	6.59	4.3	$1.5x10^5$	$1.4x10^4$
			E	9	8.1	6.2	5.7	6.3	32	60.6	0.06	3.24	20.62	26	6.55	9.7	$1.6x10^5$	$5.5x10^3$
			R	10/-6					3%	0%	14%	6%		13%	1%			

*I = Flow from Activated Sludge Process E = Effluent from Redwood Nitrification Tower
R = Percent removal where applicable
**I = Influent temperature E = Effluent temperature
R = Ambient Air Temperature Maximum/Ambient Air Temperature Minimum

APPENDIX D (CONTINUED)

																	Coliform - MF	
Period	Flow	Recycle	Sample	Temp.**	D.O.	pH	pH	pH	BOD_5	COD	NH_3-N	TKN	NO_2NO_3-N	TSS	Total P	Alk.	Total	Fecal
	MGD	MGD	Point*	°C	mg/1	Med.	Min.	Max.	mg/1	mg/1	mg/1	mg/1	mg/1	mg/1	mg/1	mg/1	#/100 ml	#/100 ml
1977 Nov.13-Nov.19	0.31	1.06	I	9	4.8	6.2	5.8	6.3	26	111	0.41	5.11	16.34	51	8.65	19	$9.5x10^5$	$2.3x10^5$
			E	9	7.7	6.8	6.4	7.0	24	101	0.33	5.53	16.48	39	8.57	21	$2.3x10^5$	$8.3x10^4$
			R	12/-4					8%	1%	19%			24%	1%			
Nov.20-Nov.26	0.32	1.06	I	7	4.9	5.8	5.3	6.4	26	127	0.04	3.33	17.00	24	5.47	8.6	$3.2x10^5$	$3.0x10^4$
			E	6	8.2	6.4	5.7	6.6	20	119	0.02	2.85	17.49	14	5.40	10	$1.8x10^5$	$3.6x10^4$
			R	2/-8					23%	6%	· 50%	14%		42%	1%			
Nov.27-Dec.3	0.30	1.04	I	9	4.3	5.6	[illegible].0	5.9	20	58.3	1.18	4.42	16.15	24	5.19	9.5	$2.4x10^5$	$4.4x10^3$
			E	7	8.0	6.5	5.7	6.7	19	54.2	0.86	4.05	17.10	24	5.17	10	$6.1x10^4$	$1.7x10^3$
			R	4/-8					5%	7%	27%	8%		0%	0%			
Dec.4-Dec.10	0.32	1.04	I	6	4.0	6.2	5.4	6.4	13	53.3	0.94	5.04	14.05	18	4.70	4.5	$4.4x10^5$	$5.1x10^4$
			E	6	8.0	6.8	6.3	7.5	9.9	43.6	0.58	4.08	14.92	16	4.71	3.1	$2.1x10^5$	$4.7x10^4$
			R	5/-8					23%	18%	38%	19%		11%	0%	31%		
Dec.11-Dec.17	0.31	1.02	I	6	3.5	6.0	5.8	6.1	14	43.9	0.48	2.78	14.49	14	4.83	11.4	$6.0x10^3$	$\leq 1.0x10^3$
			E	6	8.4	6.9	6.8	7.0	14	47.4	0.18	2.45	14.48	15	4.89	11.0	$2.5x10^4$	$1.0x10^3$
			R	4/-4					0%		62%	11%				3%		
Dec.18-Dec.24	0.29	1.04	I	5	4.0	6.1	5.9	6.4	7.5	40.4	2.22	4.23	13.55	19	5.71	25.9	$1.4x10^4$	$1.9x10^3$
			E	4	8.8	6.9	6.8	7.0	7.2	44.3	1.27	3.29	14.72	16	5.55	19.1	$1.7x10^4$	$1.0x10^3$
			R	-6/-16					4%		42%	22%		15%	2%	26%		
Dec.25-Dec.31	0.48	1.17	I	6	3.0	6.8	6.7	6.8	17	47.5	14.80	15.76	8.98	15	8.37	109	$2.0x10^6$	$1.4x10^5$
			E	6	8.5	7.6	7.5	7.7	19	44.1	14.13	15.58	10.57	14	7.71	91.9	$2.5x10^6$	$1.1x10^5$
			R	4/-10						7%	4%	1%		6%	7%	15%		
1978 Jan.1-Jan.7	0.42	0.99	I	6	3.4	6.8	6.7	6.8	20	54.2	15.24	19.48	4.05	14	8.92	102	$7.5x10^5$	$7.0x10^4$
			E	4	8.3	7.5	7.3	7.7	22	39.8	14.61	16.86	6.29	11	8.56	89.8	$6.1x10^5$	$3.0x10^4$
			R	0/-10						26%	4%	13%		21%	4%	11%		
Jan.8-Jan.14	0.38	0.99	I	6	4.8	6.8	6.7	6.9	11	49.1	12.11	12.95	3.32	13	4.82	101	$6.9x10^5$	$3.9x10^4$
			E	5	8.2	7.5	7.0	7.7	12	43.9	10.01	11.97	6.61	8.8	5.10	76.6	$2.9x10^5$	$1.4x10^4$
			R	2/-4						10%	17%	7%		32%		24%		
Jan.15-Jan.21	0.26	1.00	I	4	4.8	6.8	6.7	6.8	10	32.0	14.90	17.37	1.75	18	5.03	107	$2.3x10^4$	$1.6x10^3$
			E	4	8.5	7.5	7.2	7.6	15	29.3	9.95	12.69	7.05	13	4.96	73.0	$1.9x10^4$	$1.9x10^3$
			R	2/-14						8%	33%	26%		27%	1%	31%		

APPENDIX D (CONTINUED)

																	Coliform - MF	
Period	Flow	Recycle	Sample	Temp.**	D.O.	pH	pH	pH	BOD_5	COD	NH_3-N	TKN	NO_2NO_3-N	TSS	Total P	Alk.	Total	Fecal
	MGD	MGD	Point*	°C	mg/l	Med.	Min.	Max.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	#/100 ml	#/100 ml
1978 Jan 22 - Jan 28	0.31	1.05	I	5	4.7	6.8	6.6	6.9	9.8	41.9	14.97	17.18	1.38	19	5.17	116	$5.7x10^4$	$8.9x10^3$
			E	4	8.3	7.5	7.4	7.6	12	38.5	11.68	13.95	6.36	17	5.10	82.0	$4.3x10^4$	$6.9x10^3$
			R	-1/-13						8%	21%	18%		10%	1%	29%		
Jan 29 - Feb 4	0.40	1.01	I	6	5.2	6.9	6.8	7.2	17	56.9	14.98	16.92	1.39	21	5.00	106	$1.1x10^5$	$1.5x10^4$
			E	6	8.1	7.4	7.4	7.5	34	60.9	10.97	14.45	6.46	15	4.75	79.2	$8.5x10^4$	$5.4x10^3$
			R	3/-14							26%	14%		28%	5%	25%		
Feb 5 - Feb 11	0.37	1.00	I	6	3.4	7.0	6.9	7.1	18	61.4	17.40	21.29	0.18	24	5.87	115	$8.2x10^5$	$2.6x10^5$
			E	4	7.9	7.2	7.2	7.3	34	61.4	11.71	15.23	4.98	16	5.87	80.1	$7.6x10^5$	$1.1x10^5$
			R	6/-8						0%	32%	28%		33%	0%	30%		
Feb 12 - Feb 18	0.44	1.00	I	4	2.8	6.6	6.4	6.7	16	60.4	14.04	17.88	0.29	25	4.74	98.8	$3.2x10^5$	$3.0x10^4$
			E	3	8.1	7.3	6.6	7.4	20	54.6	10.26	14.64	3.99	20	4.62	73.3	$1.3x10^5$	$2.1x10^4$
			R	-1/-19						9%	26%	19%	-	20%	2%	25%		
Feb 19 - Feb 25	0.46	1.03	I	4	1.9	6.7	6.6	6.7	18	52.6	15.79	18.59	0.06	23	5.47	97.1	$2.9x10^5$	$6.9x10^4$
			E	4	8.1	7.5	7.4	7.5	24	46.0	12.86	15.48	3.57	22	5.18	79.0	$1.5x10^5$	$5.7x10^4$
			R	3/-7						12%	18%	17%		4%	5%	19%		
Feb 26- Mar 4	0.41	1.08	I	4	2.1	6.6	6.6	6.7	14	39.3	15.26	18.12	0.03	17	5.25	106	$7.6x10^5$	$5.5x10^4$
			E	3	8.1	7.3	7.3	7.4	22	34.7	10.81	13.50	4.53	13	5.25	74.2	$3.3x10^5$	$3.3x10^4$
			R	1/-7						12%	29%	25%		24%	0%	30%		
Mar 5 - Mar 11	0.43	1.01	I	6	2.3	6.6	6.4	6.9	12	56.0	15.12	18.18	0.10	15	14.20	113	$1.2x10^5$	$1.2x10^4$
			E	4	7.5	7.2	6.6	7.6	18	52.0	10.75	13.14	5.90	8.0	11.96	78.1	$9.2x10^4$	$7.7x10^3$
			R	8/-5						7%	29%	28%		47%	16%	31%		
Mar 12 - Mar 18	0.44	0.99	I	5	2.4	6.6	6.5	6.7	9.2	38.6	12.88	15.11	0.20	13	4.70	92.8	$2.5x10^5$	$2.6x10^4$
			E	4	7.8	7.3	6.8	7.4	12	35.6	8.19	13.16	5.08	11	4.70	64.7	$9.9x10^4$	$1.3x10^4$
			R	5/-6						8%	36%	13%		18%	0%	30%		
Mar 19 - Mar 25	0.54	0.07	I	7	2.2	6.6	6.5	6.7	18	47.1	15.77	19.06	0.07	18	4.86	108	-	$1.5x10^6$
			E	5	6.9	7.4	6.9	7.5	41	58.8	11.97	14.36	4.65	17	5.08	80.8	$6.7x10^5$	$9.0x10^4$
			R	9/-3							24%	25%		6%		25%		
Mar 26 - Apr 1	0.48	0.95	I	7	3.0	6.6	6.5	6.8	12	61.9	13.33	16.93	0.59	14	4.22	105	$5.2x10^4$	$1.8x10^4$
			E	6	7.2	7.3	7.2	7.4	26	44.6	11.21	14.54	6.42	13	4.58	72.2	$2.8x10^4$	$8.7x10^3$
			R	13/-5						28%	16%	14%		7%		31%		

APPENDIX D (CONTINUED)

																	Coliform - MF	
Period	Flow	Recycle	Sample	Temp.**	D.O.	pH	pH	pH	BOD$_5$	COD	NH$_3$-N	TKN	NO$_2$NO$_3$-N	TSS	Total P	Alk.	Total	Fecal
	MGD	MGD	Point*	°C	mg/l	Med.	Min.	Max.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	#/100 ml	#/100 ml
1978 April 2-June 8	0.57	1.02	I	8	2.9	6.6	6.4	6.7	9.3	62.1	12.00	14.82	0.47	16	6.10	98.0	6.2×10^{4}	2.1×10^{4}
			E	8	7.0	7.1	6.6	7.3	22	39.6	7.74	10.02	5.44	12	6.02	63.3	4.0×10^{4}	6.1×10^{3}
			R	-3/10						36%	36%	32%		25%	1%	36%		
April 9-April 15	0.50	1.00	I	8	3.6	6.4	6.4	6.6	14	41.9	9.85	11.06	0.60	16	4.38	106	3.5×10^{4}	5.0×10^{3}
			E	7	7.1	6.8	6.7	7.0	28	41.9	5.72	7.66	5.61	14	4.37	63.1	2.9×10^{4}	5.2×10^{3}
			R	-1/14						0%	42%	31%		12%	0%	40%		
April 16-April 22	0.39	1.05	I	8	3.8	6.6	6.6	6.7	14	51.5	13.47	15.50	0.76	13	6.18	112	4.2×10^{4}	1.5×10^{4}
			E	7	6.9	6.8	6.6	7.2	30	43.6	7.11	9.27	7.70	14	6.10	60.2	2.6×10^{4}	1.2×10^{3}
			R	-6/9						15%	47%	40%			1%	46%		
April 23-April 29	0.44	0.77	I	9	3.4	6.6	6.6	6.7	14	60.7	12.79	14.85	.27	20	7.08	116	9.3×10^{4}	2.9×10^{4}
			E	8	6.8	7.1	7.0	7.2	24	48.8	6.14	8.06	7.96	17	6.80	59.2	1.1×10^{5}	6.4×10^{3}
			R	0/10						20%	52%	46%		15%	4%	49%		
April 30-May 6	0.55	1.03	I	9	3.4	6.6	6.5	6.7	6.9	54.6	11.11	12.45	2.49	18	8.82	80.8	1.8×10^{4}	3.9×10^{3}
			E	9	6.5	7.0	6.9	7.1	25	42.7	6.16	7.18	8.40	14	8.82	50.6	7.5×10^{3}	2.2×10^{3}
			R	-5/2						22%	44%	47%		22%	0%	37%		
May 7- May 13	0.89	0.30	I	9	3.6	6.7	6.6	6.8	20	43.6	9.03	11.59	1.48	14	3.07	95.6	1.2×10^{5}	3.9×10^{4}
			E	8	6.8	7.2	6.9	7.3	19	43.6	5.12	7.32	5.15	13	2.97	58.8	9.6×10^{4}	2.8×10^{4}
			R	-3/11					5%	0%	43%	37%		7%	3%	38%		
May 14-May 20	1.10	0.00	I	10	1.8	6.6	6.4	6.7	13	47.6	7.15	10.80	1.29	9.5	4.79	92.6	1.5×10^{4}	2.1×10^{3}
			E	10	6.3	7.1	6.9	7.2	27	38.8	4.68	7.26	4.49	10	4.79	64.3	1.3×10^{4}	1.4×10^{3}
			R	-1/22						18%	34%	32%			0%	30%		
May 21-May 27	0.92	0.62	I	11	2.2	6.6	6.5	6.7	15	42.7	7.76	9.72	2.28	16	2.44	95.4	5.2×10^{4}	1.2×10^{4}
			E	11	5.8	7.1	6.9	7.3	30	44.6	4.00	5.95	5.73	15	2.44	60.9		
			R	-1/19							48%	39%		6%	0%	36%		
May 28-June 3	0.73	0.73	I	12	2.8	6.6	6.5	6.8	21	58.5	13.37	17.02	1.54	20	3.64	121		
			E	12	5.3	6.9	6.9	7.4	46	54.6	7.94	10.63	6.47	18	2.75	76.0		
			R	-1/16						7%	41%	38%		10%	24%	37%		
June 4-June 10	0.74	0.89	I	11	2.4	6.6	6.6	6.7	45	60.8	14.43	16.72	3.80	16		120		
			E	11	6.3	7.0	6.9	7.2	59	52.9	7.51	9.69	10.24	15		60.4		
			R	2/16						13%	48%	42%		6%		50%		

APPENDIX D (CONTINUED)

																	Coliform - MF	
Period	Flow	Recycle	Sample	Temp.**	D.O.	pH	pH	pH	BOD_5	COD	NH_3-N	TKN	NO_2NO_3-N	TSS	Total P	Alk.	Total	Fecal
	MGD	MGD	Point*	°C	mg/l	Med.	Min.	Max.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	#/100 ml	#/100 ml
1978 June 11-June 17	0.92	0.38	I	12	2.2	6.8	6.5	7.7	-	-	13.73	17.38	2.08	24	-	116	-	-
			E	12	5.3	7.2	6.9	7.3	-	57.6	8.14	11.56	6.65	47	-	67.3	-	-
			R	24/2							41%	34%				42%		
June 18-June 24	0.76	0.70	I	13	2.2	6.7	6.5	6.9	-	-	18.29	23.46	4.69	-	-	123	-	-
			E	13	5.4	6.9	6.8	7.2	-	-	10.87	13.72	10.47	-	-	71.1	-	-
			R	24/3							40%	42%				42%		
June 25-July 1	0.76	0.82	I	17	1.1	6.7	6.4	6.8	-	-	21.81	21.63	1.97	-	-	139	-	-
			E	15	4.2	7.1	6.9	7.1	-	67.9	13.31	16.84	9.67	-	-	80.4	-	-
			R	28/5							39%	22%				42%		
July 2-July 8	0.70	0.60	I	15	1.3	6.8	6.6	7.0	37	-	21.99	28.39	1.73	18	-	158	-	-
			E	15	-	7.1	6.8	7.3	94	-	15.18	34.98	7.44	22	-	102	-	-
			R	26/4					-1		31%			22%		35%		
July 9-July 15	0.70	0.43	I	16	1.9	6.7	6.6	6.7	67	-	17.53	17.96	10.38	23	-	106	-	-
			E	16	-	6.9	6.8	6.9	46	-	9.11	16.68	16.52	28	-	47.2	-	-
			R	26/7					31%		48%	7%				55%		
July 16-July 22	0.74	0.40	I	17	2.0	-	-	-	-	-	24.11	28.49	8.98	-	-	108	-	-
			E	17	-	-	-	-	-	-	12.96	22.04	13.96	-	-	59.7	-	-
			R	28/8							46%	23%				45%		
July 23-July 29	0.76	0.41	I	18	2.9	6.8	6.7	6.9	-	-	21.84	24.98	6.94	-	-	109	-	-
			E	18	3.9	7.0	6.9	7.1	-	-	15.93	19.49	12.18	-	-	55.2		
			R	28/4							27%	22%				49%	-	-
			I															
			E															
			R															
			I															
			E															
			R															
			I															
			E															
			R															

APPENDIX E

SUMMARY OF LABORATORY DATA - TRI MEDIA FILTRATION

																	Coliform - MF	
Period	Flow	Filters	Sample	Turbidity	D.O.	pH	pH	pH	BOD$_5$	COD	NH$_3$-N	TKN	NO$_2$NO$_3$-N	TSS	Total P	Alk.	Total	Fecal
	MGD	On Line	Point	NTU	mg/l	Med.	Min.	Max.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	#/100 ml	#/100 ml
1976			I															
			E															
			R															
			I															
			E															
			R															
			I															
			E															
			R															
Oct 10 - Oct 16	0.26	1	I	7.8	6.1	6.8	6.4	7.3	13	36.1	0.14	1.90	7.81	30	5.17	26.4	7.2x10^4	9.3x10^3
			E	1.9	5.5	6.9	6.5	7.1	5.6	24.4	0.12	1.60	9.40	12	4.86	26.1	2.1x10^4	3.7x10^3
			R	76%					57%	32%	14%	16%		61%	6%	1%		
Oct 17 - Oct 23	0.22	1	I	11	7.3	5.8	6.3	6.6	21	57.2	-	2.85	14.07	27	2.4	25.5	1.0x10^5	1.9x10^3
			E	2.1	5.8	6.3	5.7	6.7	3.7	36.9	-	2.80	12.88	4.8	-	25.8	2.7x10^4	5.7x10^2
			R	82%					82%	36%		2%		82%				
Oct 24 - Oct 30	0.18	1	I	8.1	7.3	6.2	5.8	6.4	24	50.8	0.11	2.92	13.93	28	1.80	15.4	1.2x10^5	6.8x10^3
			E	1.4	5.9	6.1	5.8	6.3	3.9	23.1	0.01	1.29	12.92	2.2	1.90	14.4	1.1x10^4	7.8x10^2
			R	82%					84%	54%	91%	56%		92%		6%		
Oct 31 - Nov 6	0.23	1	I	8.3	7.4	6.6	6.2	6.8	15	56.6	0.53	3.47	19.27	17	3.98	28.0	1.1x10^5	6.0x10^3
			E	1.4	6.4	6.4	5.8	6.7	1.0	29.4	0.16	1.44	21.88	5.3	4.10	30.5	5.8x10^4	3.2x10^3
			R	83%					93%	48%	70%	58%		32%				
Nov 7 - Nov 13	0.21	1	I	6.9	8.0	6.5	6.4	6.6	19	67.2	0.08	2.61	12.30	23	3.36	26.3	1.7x10^5	4.7x10^3
			E	1.2	6.8	6.4	6.2	6.5	2.2	54.9	0.11	1.23	11.18	4.1	3.23	28.0	1.9x10^5	2.5x10^3
			R	82%					88%	18%		53%		83%	4%			
Nov 14 - Nov 20	0.28	1	I	8.8	7.6	6.9	6.5	7.6	26	47.8	-	3.73	8.89	24	3.40	31.7	1.4x10^5	1.3x10^4
			E	1.5	6.3	6.5	6.2	7.2	7.6	23.4	0.73	1.89	8.34	3.1	2.27	30.7	1.1x10^5	6.0x10^3
			R	83%					71%	51%		49%		87%	33%	2%		
Nov 21 - Nov 27	0.20	1	I	5.7	6.6	7.2	7.0	7.7	34	55.3	1.20	3.70	7.90	30	2.60	42.7	2.4x10^5	7.3x10^4
			E	1.7	5.6	7.0	6.8	7.8	5.1	30.0	1.10	1.70	8.10	3.3	2.60	33.3	5.0x10^4	1.5x10^4
			R	71%					85%	46%	8%	54%		89%	0%	22%		

* I = Flow from Nitrification Towers
E = Effluent from Tri Media Filters
R = Percent removal where applicable

APPENDIX E (CONTINUED)

Period	Flow MGD	Filters On Line	Sample Point	Turbidity NTU	D.O. mg/l	pH Med.	pH Min.	pH Max.	BOD$_5$ mg/l	COD mg/l	NH$_3$-N mg/l	TKN mg/l	NO$_2$NO$_3$-N mg/l	TSS mg/l	Total P mg/l	Alk. mg/l	Coliform - MF Total #/100 ml	Coliform - MF Fecal #/100 ml
1976 Nov 28 - Dec 4	0.36	1	I	4.3	7.4	7.1	6.9	7.2	16	15.0	1.00	3.76	6.57	13	2.55	33.3	1.0×10^5	4.0×10^4
			E	1.0	5.8	6.9	6.7	7.1	2.6	7.8	0.93	2.22	6.41	2.0	2.39	31.3	5.4×10^4	3.3×10^4
			R	77%					84%	48%	7%	41%		85%	6%	6%		
Dec 5 - Dec 11	0.25	1	I	4.6	7.8	7.2	6.9	7.6	20	34.5	0.78	3.30	6.95	17	2.98	30.0	5.2×10^4	2.0×10^3
			E	0.87	6.6	7.0	6.8	7.2	4.5	16.0	0.51	1.04	6.70	2.5	2.61	26.5	1.3×10^4	9.2×10^2
			R	81%					78%	54%	35%	68%		86%	12%	12%		
Dec 12 - Dec 18	0.21	1	I	4.0	8.2	7.0	6.7	7.1	24	29.1	1.70	2.86	10.21	9.6	2.46	33.2	4.0×10^4	3.0×10^3
			E	0.73	5.6	6.9	6.8	6.7	3.7	21.2	1.26	2.00	7.35	1.7	2.27	30.2	3.0×10^4	1.6×10^3
			R	82%					84%	27%	26%	30%		82%	8%	9%		
Dec 19 - Dec 25	0.26	1	I	3.8	7.6	7.0	6.5	7.3	20	36.0	3.72	5.36	3.63	11	2.72	47.8	7.6×10^4	1.5×10^4
			E	0.99	5.7	7.0	7.0	7.1	4.2	26.1	3.28	3.64	4.10	2.4	2.65	45.6	3.0×10^4	2.2×10^3
			R	74%					78%	28%	12%	32%		79%	3%	5%		
Dec 26 - Jan 1	0.30	1	I	4.0	8.3	7.3	7.1	7.4	32	38.6	8.61	8.91	2.38	14	3.09	57.0	4.7×10^5	5.4×10^4
			E	1.1	6.2	7.1	7.0	7.2	7.2	25.8	6.80	7.58	2.52	2.3	3.00	55.1	2.0×10^5	2.5×10^4
			R	71%					78%	33%	21%	15%		84%	3%	3%		
1977 Jan 2 - Jan 8	0.30	1	I	4.4	8.0	7.2	7.0	7.3	22	38.9	3.93	6.09	8.67	10	3.83	47.7	2.1×10^5	4.2×10^4
			E	1.3	6.0	7.0	6.7	7.1	4.2	30.9	3.83	5.24	9.19	2.9	3.29	43.9	1.6×10^5	7.1×10^3
			R	70%					81%	21%	3%	14%		71%	14%	8%		
Jan 9 - Jan 15	0.45	1	I	4.0	8.8	7.4	7.2	7.5	25	35.3	4.28	5.78	4.66	13	3.17	52.8	5.1×10^4	1.7×10^4
			E	1.3	7.0	7.3	7.0	7.4	6.8	32.4	4.03	5.02	4.74	5.1	3.42	39.4	3.7×10^4	1.5×10^4
			R	68%					73%	8%	6%	13%		61%		25%		
Jan 16 - Jan 22	0.52	1	I	4.2	9.4	7.2	7.0	7.4	17	35.5	3.96	5.83	3.46	14	2.64	46.4	1.4×10^5	6.9×10^4
			E	1.4	8.7	7.0	7.0	7.4	6.3	37.1	3.45	4.23	3.56	3.4	2.34	43.7	7.9×10^4	2.5×10^4
			R	67%					64%		13%	27%		76%	11%	6%		
Jan 23 - Jan 29	0.50	1	I	6.3	9.1	7.4	7.2	7.7	34	49.2	4.79	6.19	3.05	13	2.92	55.9	2.4×10^5	1.7×10^5
			E	6.1	5.5	7.2	7.2	7.3	7.2	22.0	4.27	5.03	3.39	3.2	2.62	67.5	9.4×10^4	2.5×10^4
			R	3%					79%	55%	11%	19%		76%	10%			
Jan 30 - Feb 5	0.47	1	I	4.3	8.0	7.1	7.1	7.3	18	41.5	6.10	8.19	2.41	14	3.06	63.7	1.8×10^5	4.1×10^4
			E	1.6	6.6	7.2	6.9	7.2	4.4	22.0	6.32	7.26	2.54	1.6	2.82	57.0	8.9×10^4	3.0×10^4
			R	63%					75%	47%		11%		89%	8%	10%		

APPENDIX E (CONTINUED)

																	Coliform - MF	
Period	Flow	Filters	Sample	Turbidity	D.O.	pH	pH	pH	BOD_5	COD	NH_3-N	TKN	NO_2NO_3-N	TSS	Total P	Alk.	Total	Fecal
	MGD	On Line	Point	NTU	mg/l	Med.	Min.	Max.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	#/100 ml	#/100 ml
1977 Feb 6 - Feb 12	0.45	1	I	6.4	7.2	7.2	7.1	7.4	21	42.1	6.00	8.32	2.08	34	2.29	64.4	1.5×10^5	9.3×10^4
			E	2.0	5.4	7.1	7.0	7.2	6.8	27.6	5.60	6.77	2.38	8.4	2.36	54.7	2.5×10^5	7.9×10^4
			R	69%					67%	34%	7%	19%		76%		15%		
Feb 13 - Feb 19	0.48	1	I	4.0	7.5	7.2	6.9	7.5	24	34.0	6.14	8.48	1.56	10	2.51	79.5	1.4×10^5	6.5×10^4
			E	1.5	5.5	7.1	6.8	7.3	5.3	30.1	5.35	6.36	1.92	5.4	2.41	62.5	1.3×10^5	7.9×10^4
			R	63%					78%	11%	13%	25%		49%	4%	21%		
Feb 20 - Feb 26	0.48	1	I	4.	7.2	7.2	7.1	7.4	12	42.0	5.66	7.66	1.86	12	3.00	85.1	1.8×10^5	3.7×10^4
			E	1.4	4.3	7.0	6.9	7.2	4.2	34.1	4.92	6.18	2.34	3.2	2.68	59.7	2.2×10^5	3.8×10^4
			R	70%					65%	19%	13%	19%		74%	11%	30%		
Feb 27 - Mar 5	0.48	1	I	4.6	7.5	7.2	7.0	7.6	14	38.9	5.68	8.67	1.92	15	2.89	65.6	5.1×10^4	9.9×10^3
			E	1.3	4.7	7.0	6.8	7.3	3.4	23.5	5.44	6.78	2.87	3.3	2.66	60.3	4.9×10^4	7.7×10^3
			R	72%					77%	40%	4%	22%		78%	8%	8%		
Mar 6 - Mar 12	0.48	1	I	4.9	8.2	7.2	7.1	7.3	16	35.5	5.99	10.07	4.50	13	3.92	64.8	1.1×10^5	1.0×10^4
			E	1.4	4.7	7.0	6.9	7.1	5.0	27.0	5.17	6.47	5.24	2.8	3.54	54.5	9.7×10^4	3.0×10^3
			R	71%					60%	24%	14%	36%		78%	10%	16%		
Mar 13 - Mar 19	0.48	1	I	6.3	8.0	7.2	7.1	7.2	28	45.5	5.59	8.84	3.59	20	4.62	58.1	5.5×10^4	1.0×10^4
			E	2.0	4.4	7.0	6.9	7.1	8.0	25.5	4.78	6.04	4.14	6.8	4.44	55.0	5.6×10^4	1.7×10^3
			R	68%					71%	44%	14%	32%		66%	4%	5%		
Mar 20 - Mar 26	0.40	1	I	5.5	7.8	7.0	6.9	7.9	21	60.0	4.83	7.70	3.95	18	2.98	59.6	6.0×10^4	8.0×10^3
			E	1.6	3.9	6.9	6.6	7.0	5.6	32.0	4.08	5.30	5.34	3.7	2.72	53.5	6.4×10^4	4.2×10^3
			R	71%					73%	47%	16%	31%		79%	9%	10%		
Mar 27 - Apr 2	0.48	1	I	5.8	6.5	7.2	7.0	8.6	41	51.2	4.35	7.70	5.27	21	3.16	58.3	5.6×10^5	8.9×10^4
			E	2.2	3.0	6.9	6.8	7.0	10	34.8	3.46	5.80	6.30	6.0	2.82	47.0	3.1×10^5	4.5×10^4
			R	62%					76%	32%	20%	25%		71%	11%	19%		
Apr 3 - Apr 9	0.48	1	I	5.5	7.2	7.3	7.2	7.4	21	33.8	5.29	7.67	5.27	9.8	3.26	54.6	6.0×10^5	2.2×10^5
			E	1.9	2.9	7.0	6.9	7.2	5.1	26.3	4.41	5.70	6.69	2.9	2.92	44.2	5.7×10^5	7.1×10^4
			R	34%					76%	22%	17%	26%		70%	10%	19%		
Apr 10 - Apr 16	0.34	1	I	6.4	7.3	7.2	7.0	7.4	21	47.9	3.90	5.90	5.80	13	3.17	56.6	4.9×10^5	4.5×10^4
			E	3.0	3.2	7.1	6.9	7.3	11	33.6	2.80	4.57	6.59	5.1	2.84	38.8	3.2×10^5	1.7×10^4
			R	57%					48%	30%	28%	22%		61%	10%	31%		

APPENDIX E (CONTINUED)

																	Coliform - MF	
Period	Flow	Filters	Sample	Turbidity	D.O.	pH	pH	pH	BOD_5	COD	NH_3-N	TKN	NO_2NO_3-N	TSS	Total P	Alk.	Total	Fecal
	MGD	On Line	Point	NTU	mg/l	Med.	Min.	Max.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	#/100 ml	#/100 ml
1977 Apr 17 - Apr 23	0.42	1	I	7.3	8.1	7.2	7.0	7.4	32	67.0	3.67	7.43	5.56	15	3.48	57.2	8.0×10^5	2.3×10^5
			E	3.0	4.1	6.8	6.3	7.1	12	34.9	2.55	4.57	6.60	5.0	3.09	50.8	7.2×10^5	2.3×10^5
			R	63%					62%	48%	30%	38%		67%	11%	11%		
Apr 24 - Apr 30	0.66	1	I	7.1	7.1	7.0	6.9	7.1	30	62.4	2.53	5.31	6.82	12	5.59	39.9	3.0×10^5	4.9×10^4
			E	3.0	3.4	6.6	6.6	6.7	17	40.8	1.25	4.16	7.67	3.7	5.59	35.7	3.1×10^5	2.9×10^4
			R	58%					43%	35%	50%	22%		69%	0%	11%		
May 1 - May 7	0.42	1	I	4.6	7.3	7.0	7.0	7.2	24	35.8	1.13	4.50	8.57	15	3.03	25.6	2.9×10^4	9.5×10^3
			E	1.9	4.0	6.7	6.6	6.7	8.5	34.2	0.28	2.06	9.13	5.3	2.76	19.4	1.1×10^4	4.5×10^3
			R	59%					64%	4%	75%	54%		65%	9%	24%		
May 8 - May 14	0.52	1	I	6.1	6.3	6.9	6.8	7.1	28	54.3	1.33	4.31	7.59	26	3.83	36.8	8.9×10^5	1.9×10^5
			E	3.8	4.1	6.8	6.4	6.9	9.2	42.3	0.45	2.69	7.99	10	3.37	24.7	1.7×10^6	2.8×10^5
			R	38%					67%	22%	66%	38%		62%	12%	33%		
May 15 - May 21	0.52	1	I	4.7	5.6	6.8	6.7	6.9	27	62.9	1.31	4.39	7.40	14	4.80	28.0	4.7×10^5	7.0×10^4
			E	2.4	3.9	6.8	6.4	7.0	9.8	38.4	1.34	3.41	7.55	11	4.63	25.8	2.3×10^5	9.8×10^4
			R	49					64%	39%	2%	22%		27%	4%	8%		
May 22 - May 28	0.48	1	I	5.6	5.4	6.9	6.7	7.5	17	68.0	3.63	6.57	10.90	19	4.18	32.7	1.9×10^6	3.6×10^5
			E	2.9	5.4	6.9	6.6	7.1	12	52.0	3.04	5.89	10.79	7.6	4.22	23.1	6.2×10^5	2.2×10^5
			R	48%					29%	24%	16%	10%		60%		29%		
May 29 - Jun 4	0.76	1	I	5.0	5.1	6.8	6.7	6.9	32	78.5	5.78	7.76	10.16	14	4.69	47.0	3.4×10^5	2.8×10^5
			E	2.3	3.0	6.8	6.5	7.0	13	52.9	5.08	6.78	11.24	4.4	4.94	36.0	7.0×10^5	3.4×10^4
			R	54%					59%	33%	12%	13%		68%		23%		
Jun 5 - Jun 11	0.94	1	I	4.5	4.4	6.8	6.8	6.9	-	41.7	7.77	12.05	10.50	19	5.20	44.9	3.0×10^4	1.0×10^4
			E	2.7	2.9	6.6	6.2	6.7	-	30.5	7.18	9.31	10.20	9.4	4.70	51.2	1.8×10^4	4.6×10^3
			R	40%						27%	8%	23%		51%	10%			
Jun 12 - Jun 18	1.12	1	I	4.7	-	6.6	6.5	7.2	-	64.9	8.92	12.18	14.05	27	6.18	37.4	2.3×10^5	5.5×10^4
			E	2.9	0	6.5	6.4	7.0	-	49.7	7.91	9.99	12.47	10	6.00	28.8	2.9×10^4	1.1×10^4
			R	38%						23%	11%	18%		63%	3%	23%		
Jun 19 - Jun 25			I															
			E		no analyses run													
			R															

APPENDIX E (CONTINUED)

Period	Flow	Filters	Sample	Turbidity	D.O.	pH	pH	pH	BOD$_5$	COD	NH$_3$-N	TKN	NO$_2$,NO$_3$-N	TSS	Total P	Alk.	Coliform - MF Total	Coliform - MF Fecal
	MGD	On Line	Point	NTU	mg/l	Med.	Min.	Max.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	#/100 ml	#/100 ml
1977 June 26-July 2	1.11	2	I		no analyses run													
			E															
			R															
July 3-July 9	1.05	2	I	6.4	3.6	7.1	6.9	7.1	---	59.1	15.07	20.56	10.85	184	5.22	90.7	2.3×10^{5}	2.0×10^{4}
			E	2.3	3.0	7.0	6.9	7.1	---	46.9	18.13	16.90	10.85	12	5.09	94.5	7.0×10^{4}	1.4×10^{3}
			R	48%						21%		17%		93%	2%			
July 10-July 16	0.92	2	I	6.3	3.9	7.3	7.2	7.4	102	73.8	19.29	22.82	11.22	51	5.74	96.8	---	---
			E	3.9	1.7	7.2	7.0	7.2	36	54.2	17.03	22.93	10.40	8.7	5.61	93.3	1.8×10^{4}	4.0×10^{3}
			R	38%					65%	27%	12%	0%		83%	2%	4%		
July 17-July 23	0.98	2	I	7.0	2.1	7.1	7.0	7.1	125	64.7	11.53	14.89	13.22	11	5.00	62.0	4.5×10^{5}	5.1×10^{4}
			E	2.0	2.0	7.1	6.9	7.1	33	48.0	11.21	14.00	12.33	2.4	4.79	62.5	3.0×10^{5}	4.1×10^{4}
			R	71%					74%	26%	3%	6%		78%	4%			
July 24-July 30	1.02	2	I	9.7	3.3	7.2	7.0	7.3	88	96.3	13.28	17.26	9.31	46	5.46	78.0	1.6×10^{5}	3.8×10^{4}
			E	2.3	2.4	7.1	6.9	7.2	28	43.2	14.68	17.24	6.46	7.4	5.20	95.6	3.3×10^{5}	5.7×10^{4}
			R	76%					68%	55%		0%		84%	4%			
July 31-Aug.6	1.12	2	I	11.8	2.3	7.2	7.0	7.4	107	200	18.53	30.69	11.66	104	7.66	104	---	---
			E	3.2	2.3	7.1	6.8	7.2	56	60.7	18.89	22.84	8.66	20	5.62	105	---	---
			R	76%					47%	69%		25%		80%	26%	0%		
Aug.7-Aug.13	0.93	2	I	6.9	3.3	7.1	7.0	7.2	99	79.2	16.69	21.63	13.40	22	5.85	83.8	---	---
			E	2.4	2.2	7.1	6.8	7.2	27	40.9	16.06	18.62	12.99	2.7	5.43	79.0	---	---
			R	65%					72%	48%	3%	13%		87%	7%	5%		
Aug.14-Aug.20	1.03	2	I	9.2	3.5	7.1	6.9	7.2	290	89.7	10.53	15.61	14.00	37	5.47	64.1	---	---
			E	3.1	2.1	6.9	6.8	7.1	41	37.5	10.26	12.20	12.62	3.3	5.01	86.0	1.0×10^{5}	1.0×10^{4}
			R	66%					85%	58%	2%	21%		91%	8%			
Aug.21-Aug.27	0.77	2	I	4.0	3.8	6.8	6.5	7.0	74	78.6	10.60	15.91	24.19	34	4.69	67.0	3.5×10^{4}	1.7×10^{3}
			E	1.3	3.0	6.8	6.2	7.1	43	52.6	11.28	12.50	21.70	3.2	4.29	[illegible]	2.4×10^{4}	3.6×10^{3}
			R	67%					41%	33%		21%		90%	8%	[illegible]		
Aug.28-Sept.3	0.49	2	I	2.9	4.9	6.0	5.3	6.9	62	63.0	9.24	12.68	21.63	23	6.72	23.3	3.5×10^{4}	6.0×10^{2}
			E	1.2	2.9	6.0	5.6	6.8	14	40.8	8.99	8.43	21.99	3.6	6.65	25.5	5.5×10^{3}	3.3×10^{2}
			R	59%					77%	35%	3%	33%		84%	1%			

APPENDIX E (CONTINUED)

																	Coliform - MF	
Period	Flow	Filters	Sample	Turbidity	D.O.	pH	pH	pH	BOD$_5$	COD	NH$_3$-N	TKN	NO$_2$NO$_3$-N	TSS	Total P	Alk.	Total	Fecal
	MGD	On Line	Point	NTU	mg/l	Med.	Min.	Max.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	#/100 ml	#/100 ml
1977 Sept. 4-Sept. 10	0.54	2	I	5.7	6.2	6.3	6.1	6.8	11	50.7	0.65	3.69	20.91	22	5.44	11.4	$6.6\mathrm{x}10^4$	$2.6\mathrm{x}10^3$
			E	1.7	4.8	6.5	5.4	6.9	5.2	36.8	0.60	2.20	20.41	3.8	5.12	8.4	$1.3\mathrm{x}10^4$	$1.9\mathrm{x}10^3$
			R	70%					53%	27%	8%	40%		83%	6%	26%		
Sept. 11-Sept. 1	0.56	2	I	5.4	6.5	6.8	6.4	6.9	20	49.5	0.13	2.54	13.15	28	4.66	25.9	$4.6\mathrm{x}10^4$	$2.4\mathrm{x}10^2$
			E	1.2	5.2	6.6	6.4	6.8	3.0	37.0	0.06	1.13	12.62	7.0	4.50	24.2	-	-
			R	77%					85%	25%	38%	56%		75%	3%	6%		
Sept. 18-Sept. 2	0.58	2	I	7.3	6.1	6.9	6.6	7.2	43	65.4	3.60	6.50	11.92	24	4.10	30.4	$3.8\mathrm{x}10^4$	$1.2\mathrm{x}10^3$
			E	1.9	4.3	6.5	6.3	7.0	-	27.7	0.10	3.95	-	3.3	4.00	28.4	$4.4\mathrm{x}10^3$	$1.7\mathrm{x}10^2$
			R	74%					-	58%	97%	39%	-	86%	2%	6%		
Sept. 25-Oct. 1	0.49	1	I	12	6.0	7.2	6.8	7.4	82	113	9.38	13.61	11.43	69	8.27	62.0	$1.6\mathrm{x}10^5$	$1.5\mathrm{x}10^4$
			E	3.8	2.8	6.9	6.8	7.0	27	71.6	8.68	11.50	11.08	41	9.16	-	$2.5\mathrm{x}10^4$	$3.3\mathrm{x}10^4$
			R	68%					67%	37%	7%	16%		40%	10%			
Oct. 2-Oct. 8	0.40	1	I	8.8	6.7	6.8	6.2	7.0	31	68.1	0.38	5.82	12.88	29	5.61	29.2	$1.9\mathrm{x}10^4$	$1.0\mathrm{x}10^4$
			E	2.2	4.1	6.6	6.2	7.0	10	36.1	0.16	1.18	17.55	3.2	4.78	-	$3.0\mathrm{x}10^4$	$4.0\mathrm{x}10^3$
			R	75%					68%	47%	58%	80%		89%	15%			
Oct. 9-Oct. 15	0.40	1	I	7.6	6.9	6.8	6.3	6.9	28	75.4	0.63	6.37	16.18	33	7.10	13.8	$1.0\mathrm{x}10^4$	$8.4\mathrm{x}10^2$
			E	3.3	5.1	6.5	6.2	6.9	5.5	28.4	0.47	2.99	16.06	15	7.28	9.1	$7.4\mathrm{x}10^2$	$3.3\mathrm{x}10^2$
			R	56%					80%	62%	25%	53%		54%		34%		
Oct. 16-Oct. 22	0.36	1	I	5.5	7.2	6.5	6.2	6.7	20	47.4	0.03	2.53	16.67	24	5.05	7.0	-	-
			E	1.1	5.1	6.3	6.1	6.9	3.2	29.6	0.06	1.12	17.96	3.4	4.82	9.0	$1.0\mathrm{x}10^4$	$5.2\mathrm{x}10^2$
			R	80%					84%	38%		56%		86%	4%			
Oct. 23-Oct. 29	0.37	1	I	14	7.6	6.4	6.0	6.7	30	68.8	0.05	3.98	17.95	34	5.48	7.8	$1.1\mathrm{x}10^5$	$4.6\mathrm{x}10^3$
			E	4.1	6.4	6.3	6.0	6.8	5.2	41.0	0.01	2.47	17.58	10	5.04	7.6	$6.9\mathrm{x}10^4$	$2.5\mathrm{x}10^3$
			R	71%					83%	40%	80%	38%		70%	8%	2%		
Oct. 30-Nov. 5	0.36	1	I	11	7.6	6.8	5.7	6.9	30	71.0	<0.01	4.28	15.08	29	5.48	17.7	$6.7\mathrm{x}10^5$	$4.5\mathrm{x}10^4$
			E	4	5.6	6.6	5.6	7.0	7.4	42.9	0.03	2.45	14.66	9.2	4.68	17.1	$1.9\mathrm{x}10^5$	$8.2\mathrm{x}10^3$
			R	63%					75%	40%		43%		68%	14%	3%		
Nov. 6-Nov. 12	0.27	1	I	8	8.1	6.2	5.7	6.3	32	60.6	0.06	3.24	20.62	26	6.55	9.7	$1.6\mathrm{x}10^5$	$5.5\mathrm{x}10^3$
			E	2	5.7	6.1	6.0	6.3	8.2	31.1	0.55	1.99	20.56	7.3	6.38	4.8	$6.1\mathrm{x}10^4$	$3.7\mathrm{x}10^3$
			R	75%					74%	49%		38%		72%	2%	50%		

APPENDIX E (CONTINUED)

Period	Flow	Filters	Sample	Turbidity	D.O.	pH	pH	pH	BOD$_5$	COD	NH$_3$-N	TKN	NO$_2$NO$_3$-N	TSS	Total P	Alk.	Coliform - MF	
																	Total	Fecal
	MGD	On Line	Point	NTU	mg/l	Med.	Min.	Max.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	#/100 ml	#/100 ml
1977 Nov.13-Nov.19	0.31	1	I	14	7.7	6.8	6.4	7.0	24	101	0.33	5.53	16.48	39	8.57	21.0	2.3×10^5	8.3×10^4
			E	6.5	5.8	6.6	6.5	6.8	9.2	73	0.15	5.04	16.68	23	8.26	10.9	2.2×10^5	4.8×10^4
			R	57%					62%	28%	54%	9%		41%	4%	48%		
Nov.20-Nov.26	0.32	1	I	5.8	8.2	6.4	5.7	6.6	20	119	0.02	2.85	17.49	14	5.40	10.0	1.8×10^5	3.6×10^4
			E	1.9	6.9	6.3	5.4	6.4	4.5	101	0.27	2.06	17.20	4.0	4.90	10.4	2.7×10^5	3.2×10^4
			R	66%					77%	15%		28%		71%	9%			
Nov.27-Dec.3	0.30	1	I	5.5	8.0	6.5	5.7	6.7	19	54.2	0.86	4.05	17.10	24	5.17	10.0	6.1×10^4	1.7×10^3
			E	1.7	6.6	6.3	5.3	6.5	4.5	26.5	0.85	2.14	17.03	5.3	5.07	8.8	3.3×10^4	1.1×10^3
			R	69%					76%	51%	1%	47%		78%	19%	12%		
Dec.4-Dec.10	0.32	1	I	5.9	8.0	6.8	6.1	7.5	9.9	43.6	0.58	4.08	14.92	16	4.71	3.1	2.1×10^5	4.7×10^4
			E	2.0	6.7	6.6	6.2	7.2	1.8	28.7	0.29	2.07	15.46	4.5	4.43	3.4	1.2×10^5	1.6×10^4
			R	66%					81%	34%	50%	49%		71%	5%			
Dec.11-Dec.17	0.31	1	I	5.5	8.4	6.9	6.8	7.0	14	47.4	0.18	2.45	14.48	15	4.89	11.0	2.5×10^4	1.0×10^3
			E	1.3	7.2	6.7	6.5	6.9	2.6	29.6	0.06	1.44	14.40	3.4	4.43	9.4	2.0×10^3	1.0×10^3
			R	76%					81%	37%	66%	41%		77%	9%	14%		
Dec.18-Dec.24	0.29	1	I	5.5	8.8	6.9	6.8	7.0	7.2	44.3	1.27	3.29	14.72	16	5.55	19.1	1.7×10^4	1.0×10^3
			E	2.0	6.8	6.4	6.3	6.9	1.8	22.6	0.78	1.68	13.76	4.7	5.25	13.0	2.5×10^3	4.2×10^2
			R	63%					75%	48%	38%	49%		70%	5%	31%		
Dec.25-Dec.31	0.48	1	I	4.0	8.5	7.6	7.5	7.7	19	44.1	14.13	15.58	10.57	14	7.71	91.9	2.5×10^6	1.1×10^5
			E	2.3	6.2	7.4	7.0	7.5	8.0	37.2	12.88	14.07	11.45	5.5	7.50	45.0	8.0×10^5	1.3×10^5
			R	42%					57%	15%	8%	9%		65%	2%	51%		
1978 Jan.1-Jan.7	0.42	1	I	4.0	8.3	7.5	7.3	7.7	22	39.8	14.61	16.86	6.29	11	8.56	89.8	6.1×10^5	3.0×10^4
			E	2.0	5.4	7.2	7.1	7.3	6.6	30.5	11.88	13.77	7.31	4.6	7.30	81.6	2.0×10^5	1.8×10^4
			R	50%					70%	23%	19%	18%		58%	14%	9%		
Jan.8-Jan.14	0.38	1	I	3.8	8.2	7.5	7.0	7.7	12	43.9	10.01	11.97	6.61	8.8	5.10	76.6	2.9×10^5	1.4×10^4
			E	1.6	4.8	7.1	6.9	7.3	3.8	34.1	9.43	10.95	7.14	2.7	4.82	67.0	7.9×10^4	6.5×10^3
			R	57%					68%	22%	5%	8%		69%	5%	12%		
Jan.15-Jan.21	0.26	1	I	3.8	8.5	7.5	7.2	7.6	15	29.3	9.95	12.69	7.05	13	4.96	73.0	1.9×10^4	1.9×10^3
			E	1.0	4.7	7.0	6.9	7.2	3.8	17.3	8.84	10.44	8.53	2.6	4.55	61.4	6.0×10^3	2.4×10^3
			R	73%					74%	40%	11%	17%		80%	8%	15%		

APPENDIX E (CONTINUED)

																	Coliform - MF	
Period	Flow	Filters	Sample	Turbidity	D.O.	pH	pH	pH	BOD$_5$	COD	NH$_3$-N	TKN	NO$_2$NO$_3$-N	TSS	Total P	Alk.	Total	Fecal
	MGD	On Line	Point	NTU	mg/l	Med.	Min.	Max.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	#/100 ml	#/100 ml
1978 Jan 22 - Jan 28	0.35	1	I	5.5	8.3	7.5	7.4	7.6	12	38.5	11.68	13.95	6.36	17	5.10	82.0	4.3×10^4	6.9×10^3
			E	1.7	5.8	7.2	6.9	7.3	5.4	23.9	10.77	11.97	6.00	4.2	4.74	76.8	1.5×10^4	3.5×10^3
			R	69%					55%	38%	7%	14%		75%	7%	6%		
Jan 29 - Feb 4	0.40	1	I	5.8	8.1	7.4	7.4	7.5	34	60.9	10.97	14.45	6.46	15	4.75	79.2	8.9×10^4	5.4×10^3
			E	1.7	3.4	7.2	7.1	7.3	6.7	30.4	8.91	11.41	6.55	3.5	3.94	66.1	7.3×10^4	1.4×10^4
			R	71%					80%	50%	18%	21%		76%	17%	16%		
Feb 5 - Feb 11	0.37	1	I	6.2	7.9	7.2	7.2	7.3	34	61.4	11.71	15.23	4.98	16	5.87	80.1	7.6×10^5	1.1×10^5
			E	2.1	6.1	7.1	6.9	7.1	12	39.2	10.52	12.93	5.36	4.9	5.41	64.5	3.7×10^5	9.1×10^4
			R	66%					64%	36%	10%	15%		69%	7%	19%		
Feb 12 - Feb 18	0.44	1	I	8.4	8.1	7.3	6.6	7.4	20	54.6	10.26	14.64	3.99	20	4.62	73.3	1.3×10^5	2.1×10^4
			E	2.2	6.1	7.1	6.9	7.2	6.6	31.2	9.70	12.06	4.72	4.6	4.56	67.8	1.1×10^5	1.6×10^4
			R	74%					67%	42%	5%	17%		77%	1%	7%		
Feb 19 - Feb 25	0.46	1	I	6.4	8.1	7.5	7.4	7.5	24	46.0	12.86	15.48	3.57	22	5.18	79.0	1.5×10^5	5.7×10^4
			E	2.3	5.1	7.2	7.0	7.2	11	23.7	11.45	13.66	4.12	6.6	4.89	67.8	1.1×10^5	5.2×10^4
			R	64%					62%	48%	11%	12%		70%	6%	14%		
Feb 26 - Mar 4	0.41	1	I	4.3	8.1	7.3	7.3	7.4	22	34.7	10.81	13.50	4.53	13	5.24	74.2	3.3×10^5	3.3×10^4
			E	1.4	4.6	7.0	6.8	7.1	5.6	25.6	9.52	11.89	5.70	3.6	5.34	65.1	2.1×10^5	2.9×10^4
			R	67%					74%	26%	12%	12%		72%		12%		
Mar 5 - Mar 11	0.43	1	I	3.4	7.5	7.2	6.6	7.6	18	52.0	10.75	13.14	5.90	8.0	11.96	78.1	9.2×10^4	7.7×10^3
			E	1.4	3.9	6.9	6.8	7.1	5.2	43.0	8.93	11.58	7.21	5.6	11.96	70.9	3.7×10^4	1.2×10^4
			R	59%					71%	17%	17%	12%		30%	0%	9%		
Mar 12 - Mar 18	0.44	1	I	2.9	7.8	7.3	6.8	7.4	12	35.6	8.19	13.16	5.08	[illegible]	4.70	64.7	9.9×10^4	1.3×10^4
			E	1.2	4.5	6.9	6.8	7.2	3.8	27.8	7.00	8.68	6.34	3.5	4.69	52.3	1.2×10^5	1.6×10^4
			R	59%					68%	22%	14%	34%		68%	0%	19%		
Mar 19 - Mar 25	0.54	1	I	5.7	6.9	7.4	6.9	7.5	41	58.8	11.97	14.36	4.65	17	5.08	80.8	6.7×10^5	9.0×10^4
			E	2.0	3.8	7.1	7.0	7.1	16	36.6	10.42	12.74	5.79	6.2	4.89	75.6	3.9×10^5	7.1×10^4
			R	65%					61%	38%	13%	11%		64%	4%	6%		
Mar 26 - Apr 1	0.48	1	I	3.7	7.2	7.3	7.2	7.4	26	44.6	11.21	14.54	6.42	13	4.58	72.2	2.8×10^4	8.7×10^3
			E	1.8	3.9	6.9	6.9	7.0	10	36.7	10.37	12.33	7.57	2.8	4.21	49.6	1.5×10^4	1.1×10^4
			R	51%					62%	18%	7%	15%		78%	8%	31%		

APPENDIX E (CONTINUED)

																	Coliform - MF	
Period	Flow	Filters	Sample	Turbidity	D.O.	pH	pH	pH	BOD$_5$	COD	NH$_3$-N	TKN	NO$_2$NO$_3$-N	TSS	Total P	Alk.	Total	Fecal
	MGD	On Line	Point	NTU	mg/l	Med.	Min.	Max.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	#/100 ml	#/100 ml
1978 April 2-April 8	0.57	1	I	3.8	7.0	7.1	6.6	7.3	22	39.6	7.74	10.02	5.44	12	6.02	63.3	$4.0x10^4$	$6.1x10^3$
			E	1.2	2.9	6.8	6.4	6.9	14	31.7	6.51	8.09	6.64	2.8	5.85	52.0	$8.4x10^3$	$7.8x10^3$
			R	68%					36%	20%	16%	19%		77%	3%	18%		
April 9-April 15	0.50	1	I	3.6	7.1	6.8	6.7	7.0	28	41.9	5.72	7.66	5.61	14	4.37	63.1	$2.9x10^4$	$5.2x10^3$
			E	1.1	2.7	6.7	6.6	6.9	12	30.1	5.11	5.98	6.33	3.1	4.33	61.8	$1.8x10^4$	$4.7x10^3$
			R	69%					57%	28%	11%	22%		79%	1%	2%		
April 16-April 22	0.39	1	I	4.1	6.9	6.8	6.6	7.2	30	43.6	7.11	9.27	7.70	14	6.10	60.2	$2.6x10^4$	$1.2x10^3$
			E	1.2	2.3	6.9	6.8	6.9	24	39.9	6.01	7.40	5.97	2.2	5.78	62.3	$5.5x10^3$	$6.9x10^2$
			R	71%					20%	85%	15%	20%		84%	52%			
April 23-April 29	0.44	1	I	4.6	6.8	7.1	7.0	7.2	24	48.8	6.14	8.06	7.96	17	6.80	59.2	$1.1x10^5$	$6.4x10^3$
			E	1.6	2.8	7.1	6.8	7.2	22	40.9	5.24	6.45	3.85	4.8	6.53	72.4	$1.2x10^5$	$1.5x10^4$
			R	65%					8%	16%	15%	20%		72%	4%			
April 30-May 6	0.55	1	I	4.7	6.5	7.0	6.9	7.1	25	42.7	6.16	7.18	8.40	14	8.82	50.6	$7.5x10^3$	$2.2x10^3$
			E	1.8	1.4	7.1	6.9	7.3	14	30.2	4.38	5.89	4.35	3.6	8.58	63.9	$3.5x10^3$	$1.0x10^3$
			R	62%					44%	29%	29%	18%		74%	3%			
May 7 - May 13	0.89	1 & 2	I	5.8	6.8	7.2	6.9	7.3	19	43.6	5.12	7.32	5.15	13	2.97	58.8	$9.6x10^4$	$2.8x10^4$
			E	1.7	1.2	6.9	6.7	7.1	17	33.7	4.92	6.29	3.03	1.7	-	65.1	$1.7x10^4$	$9.0x10^3$
			R	71%					11%	23%	4%	14%		87%				
May 14-May 20	1.10	2	I	5.1	6.3	7.1	6.9	7.2	27	38.8	4.68	7.26	4.49	10	4.79	64.3	$1.3x10^4$	$1.4x10^3$
			E	1.0	0.9	6.8	6.7	6.9	5.0	27.2	4.51	6.64	4.65	2.8	4.79	69.3	$4.0x10^3$	$4.0x10^2$
			R	80%					81%	30%	4%	8%		72%	0%			
May 21-May 27	0.92	2	I	4.2	5.8	7.1	6.9	7.3	30	44.6	4.00	5.95	5.73	15	2.44	60.9	-	-
			E	1.4	1.1	7.0	6.9	7.1	14	34.0	3.02	4.35	6.00	2.6	2.15	63.8	$2.1x10^4$	$5.0x10^3$
			R	67%					53%	24%	25%	27%		83%	12%			
May 28-June 3	0.73	2	I	4.4	5.3	6.9	6.9	7.4	46	54.6	7.94	10.63	6.47	18	2.75	76.0	-	-
			E	1.8	2.1	7.0	6.9	7.3	18	43.4	7.32	9.68	3.99	3.2	2.91	86.1	$1.0x10^5$	$2.0x10^4$
			R	59%					61%	21%	8%	9%		82%				
June 4-June 10	0.74	2	I	5.2	6.1	7.0	6.9	7.2	59	52.9	7.51	9.69	10.24	15	-	60.4	-	-
			E	2.1	1.4	7.0	6.9	7.3	18	44.1	7.22	8.23	4.86	4.9	-	52.5	-	-
			R	60%					69%	17%	4%	15%		67%		13%		

APPENDIX E (CONTINUED)

																	Coliform - MF	
Period	Flow	Filters	Sample	Turbidity	D.O.	pH	pH	pH	BOD$_5$	COD	NH$_3$-N	TKN	NO$_2$NO$_3$-N	TSS	Total P	Alk.	Total	Fecal
	MGD	On Line	Point	NTU	mg/l	Med.	Min.	Max.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	#/100 ml	#/100 ml
1978 June 11-17	0.92	3	I	5.8	5.3	7.2	6.9	7.3		57.6	8.14	11.56	6.65	47		67.3		
			E	2.8	1.6	7.2	7.0	7.7		51.8	7.72		0.88					
			R							10%	5%							
June 18-24	0.76	2	I	5.4	5.4	6.9	6.8	7.2			10.87	13.72	10.47			71.1		
			E	2.0	2.7	6.9	6.7	7.1			10.89		6.66				5.7×10^5	1.3×10^5
			R								0%							
June 25-July 1	0.76	2	I	5.7	4.2	7.1	6.9	7.1		67.9	13.31	16.84	9.67			80.4		
			E	2.1	2.0				35	50.5				2.2				
			R							26%								
July 2-8	0.70	2	I	6.8		7.1	6.8	7.3	94		15.19	34.98	7.44	22		102		
			E	2.5														
			R															
July 9-15	0.70	2	I	5.2		6.9	6.8	6.9	46		9.11	16.68	16.52	28		47.2		
			E	2.0														
			R															
July 16-24	0.74	2	I	3.9							12.96	22.04	13.96			59.7		
			E	1.7														
			R															
July 23-29	0.76	2	I	3.9	3.9	7.0	6.9	7.1			15.93	19.49	12.18			55.2		
			E	1.8														
			R															
			I															
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APPENDIX F

SUMMARY OF LABORATORY DATA - OZONE DISINFECTION

																Coliform - MF	
Period	Flow MGD	Sample Point*	Turbidity NTU	D.O. mg/l	pH Med.	pH Min.	pH Max.	BOD$_5$ mg/l	COD mg/l	NH$_3$-N mg/l	TKN mg/l	NO$_2$NO$_3$-N mg/l	TSS mg/l	Total P mg/l	Alk. mg/l	Total #/100 ml	Fecal #/100 ml
1976 Nov 28 - Dec 4	0.36	I															
		E															
		R															
Dec 5 - Dec 11	0.25	I															
		E															
		R															
Dec 12 - Dec 18	0.21	I		5.6	6.9	6.8	6.7	3.7	21.2	1.26	2.00	7.85	1.7	2.27	30.2	3.0×10^4	1.6×10^3
		E		9.5	6.8	6.7	6.9	3.4	19.2	1.12	1.50	7.08	2.2	2.06	29.0	< 1	< 1
		R						8%	9%	11%	25%			9%	4%		
Dec 19 - Dec 25	0.26	I		5.7	7.0	7.0	7.1	4.2	26.1	3.28	3.64	4.10	2.4	2.65	45.6	3.0×10^4	2.2×10^3
		E		9.0	6.9	6.8	7.0	6.1	30.6	2.98	3.42	3.89	1.9	2.27	43.6	29	6
		R								9%	6%		22%	14%	4%		
Dec 26 - Jan 1	0.30	I		6.2	7.1	7.0	7.2	7.2	25.8	6.80	7.58	2.52	2.3	3.00	55.1	2.0×10^5	2.5×10^4
		E		9.4	7.1	5.4	7.2	6.8	17.1	5.97	6.84	2.26	2.3	2.66	51.3	35	9
		R						6%	34%	12%	10%		0%	11%	7%		
1977 Jan 2 - Jan 8	0.30	I		6.0	7.0	6.7	7.1	4.1	30.9	3.83	5.24	9.19	2.9	3.29	43.9	1.6×10^5	7.1×10^3
		E		9.2	7.0	6.0	7.2	4.7	21.0	3.68	5.21	8.74	2.[illegible]	3.65	45.4	15	8
		R							32%	4%	1%		5%		-		
Jan 9 - Jan 15	0.45	I		7.0	7.2	7.0	7.4	6.8	32.4	4.03	5.02	4.74	5.1	3.42	39.4	3.7×10^4	1.5×10^4
		E		9.0	7.2	6.6	7.3	6.6	-	4.03	3.63	4.40	2.7	3.21	38.0	15	2
		R						3%		0%	28%		47%	6%	4%		
Jan 16 - Jan 22	0.62	I		8.7	7.0	7.0	7.4	6.3	37.1	3.45	4.23	3.56	3.4	2.34	43.7	7.9×10^4	2.5×10^4
		E		10.5	7.0	6.7	7.4	4.0	20.8	3.45	3.84	3.48	3.4	2.23	36.8	49	15
		R						36%	44%	0%	9%		0%	5%	16%		
Jan 23 - Jan 29	0.50	I		5.5	7.2	7.2	7.3	7.2	22.0	4.27	5.03	3.39	3.2	2.62	67.5	9.4×10^4	2.5×10^4
		E		10.2	7.2	6.9	7.2	6.4	25.1	4.09	3.72		2.6	2.43	51.1	16	1
		R						11%		4%	26%		19%	7%	9%		
Jan 30 - Feb 5	0.47	I		6.6	7.2	7.0	7.2	4.4	22.0	6.32	7.26	2.54	1.6	2.82	57.0	8.9×10^4	3.0×10^4
		E		9.9	7.1	7.0	7.2	5.9	23.0	5.33	7.67	2.48	1.2	2.58	53.7	< 1	< 1
		R						25%		16%			25%	9%	6%		

* I = Flow from Tri Media Filters
E = Effluent from Ozone Contact Basin
R = Percent removal where applicable

APPENDIX F (CONTINUED)

Period	Flow	Sample Point*	Turbidity	D.O.	pH	pH	pH	BOD$_5$	COD	NH$_3$-N	TKN	NO$_2$NO$_3$-N	TSS	Total P	Alk.	Coliform - MF	
																Total	Fecal
	MGD		NTU	mg/l	Med.	Min.	Max.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	#/100 ml	#/100 ml
1977 Feb 6 - Feb 12	0.45	I		5.6	7.1	7.0	7.2	6.8	27.6	5.60	6.77	2.38	8.4	2.36	54.7	2.5×10^5	7.9×10^4
		E		8.9	7.1	6.8	7.2	4.8	17.3	4.70	5.57	2.52	6.4	1.78	49.1	1	1
		R						29%	37%	16%	18%		23%	24%	10%		
Feb 13 - Feb 19	0.48	I		5.5	7.1	6.8	7.3	5.3	30.1	5.35	6.36	1.92	5.4	2.41	62.5	1.3×10^5	7.9×10^4
		E		9.1	7.1	6.9	7.4	5.2	21.7	4.74	5.95	2.27	2.4	2.33	59.0	<1	<1
		R						2%	28%	11%	6%		56%	3%	6%		
Feb 20 - Feb 26	0.48	I		4.3	7.0	6.9	7.2	4.2	34.1	4.92	6.18	2.34	3.2	2.68	59.7	2.2×10^5	3.8×10^4
		E		8.7	7.1	7.0	7.3	4.6	23.0	4.38	5.17	2.48	2.3	2.53	58.9	2	<1
		R							32%	11%	16%		28%	6%	1%		
Feb 27 - Mar 5	0.48	I		4.7	7.0	6.8	7.3	3.4	23.5	5.44	6.78	2.87	3.3	2.66	60.3	4.9×10^4	7.7×10^3
		E		8.4	7.0	6.8	7.4	4.9	15.3	4.78	5.85	2.84	2.8	2.54	55.7	8	2
		R							35%	12%	14%		15%	4%	8%		
Mar 6 - Mar 12	0.48	I		4.7	7.0	6.9	7.1	5.0	27.0	5.17	6.47	5.24	2.8	3.54	54.5	9.7×10^4	3.0×10^3
		E		8.3	7.0	6.9	7.1	5.4	21.6	4.79	5.31	4.45	2.5	3.54	56.2	1.1×10^2	46
		R							20%	7%	18%		10%	0%			
Mar 13 - Mar 19	0.48	I		4.4	7.0	6.9	7.1	8.0	25.5	4.78	6.04	4.14	6.8	4.44	55.0	5.6×10^4	1.7×10^3
		E		8.0	7.0	6.8	7.2	6.4	27.5	4.54	6.18	4.16	5.1	4.32	60.2	1.1×10^3	1.4×10^2
		R						20%		5%			25%	3%			
Mar 20 - Mar 26	0.40	I		3.9	6.9	6.6	7.0	5.6	32.0	4.08	5.30	5.04	3.7	2.72	53.5	6.4×10^4	4.2×10^3
		E		8.5	6.9	6.7	7.0	5.3	28.1	3.52	4.97	4.91	4.3	2.59	49.8	36	7
		R						5%	12%	14%	6%			5%	7%		
Mar 27 - Apr 2	0.48	I		3.0	6.9	6.8	7.0	10	34.8	3.46	5.80	6.30	6.0	2.82	47.0	3.1×10^5	4.5×10^4
		E		8.5	6.8	6.7	6.9	5.2	31.6	3.24	4.85	6.18	3.1	2.69	49.1	24	18
		R						48%	9%	6%	16%		48%	5%	4%		
Apr 3 - Apr 9	0.48	I		2.9	7.0	6.9	7.2	5.1	26.3	4.41	5.70	6.69	2.9	2.92	44.2	5.7×10^5	7.1×10^4
		E		8.5	7.0	6.8	7.2	4.2	21.5	4.01	4.69	6.44	2.2	2.75	41.0	11	4
		R						18%	18%	9%	17%		24%	6%	7%		
Apr 10 - Apr 16	0.34	I		3.2	7.1	6.9	7.3	11	33.6	2.80	4.57	6.59	5.1	2.84	38.8	3.2×10^5	1.7×10^4
		E		9.2	7.1	6.3	7.1	5.8	29.5	2.13	3.67	6.32	2.3	2.64	42.9	17	2
		R						47%	12%	24%	20%		55%	7%	11%		

APPENDIX F (CONTINUED)

																Coliform - MPN	
Period	Flow	Sample Point*	Turbidity	D.O.	pH	pH	pH	BOD_5	COD	NH_3-N	TKN	NO_2NO_3-N	TSS	Total P	Alk.	Total	Fecal
	MGD		NTU	mg/1	Med.	Min.	Max.	mg/1	mg/1	mg/1	mg/1	mg/1	mg/1	mg/1	mg/1	#/100 ml	#/100 ml
1977 Apr 17 - Apr 23	0.42	I	-	4.1	6.8	6.3	7.1	12	34.9	2.55	4.57	6.60	5.0	3.09	50.8	2.4×10^5	2.1×10^5
		E	-	10.3	6.9	6.8	7.1	10	34.8	2.23	3.88	6.08	1.2	2.86	48.6	36	16
		R						20%	0%	12%	15%		76%	7%	4%		
Apr 24 - Apr 30	0.66	I	-	3.4	6.6	6.6	6.7	17	40.8	1.25	4.16	7.67	3.7	5.59	35.7	3.4×10^5	2.9×10^5
		E	-	8.6	6.8	6.7	6.9	6.6	37.8	1.04	2.92	7.05	2.8	5.42	32.8	4.4×10^3	3.7×10^3
		R						61%	7%	17%	30%		24%	3%	8%		
May 1 - May 7	0.42	I	-	4.0	6.7	6.6	6.7	8.5	34.2	0.28	2.06	9.13	5.3	2.76	19.4	2.0×10^4	1.2×10^4
		E	-	8.1	6.7	6.5	6.8	6.2	26.0	0.41	1.97	8.64	5.0	2.75	22.5	1.9×10^2	1.3×10^2
		R						27%	24%		4%		6%	0%	16%		
May 8 - May 14	0.52	I	3.8	4.1	6.8	6.4	6.9	9.2	42.3	0.45	2.69	7.99	10	3.37	24.7	1.7×10^6	6.0×10^5
		E	1.8	7.8	6.7	6.7	6.8	6.6	39.7	0.54	2.60	7.47	9.1	3.13	23.6	3.4×10^2	1.5×10^2
		R	53%					28%	6%		3%		9%	7%	4%		
May 15 - May 21	0.52	I	2.4	3.9	6.8	6.4	7.0	9.8	38.4	1.34	3.41	7.55	11	4.63	25.8	2.3×10^5	9.8×10^4
		E	2.2	7.6	6.7	6.6	6.8	6.6	31.4	1.08	2.58	6.68	5.5	4.30	25.0	9.9×10^2	3.8×10^2
		R	8%					32%	18%	19%	24%		50%	7%	3%		
May 22 - May 28	0.48	I	2.9	5.4	6.9	6.6	7.1	12	52.0	3.04	5.89	10.79	7.6	4.22	23.1	2.0×10^5	1.2×10^5
		E	2.5	7.4	6.8	6.7	7.1	8	54.8	2.67	4.64	10.28	5.7	3.73	25.6	1.8×10^4	6.1×10^3
		R	14%					33%	5%	12%	21%		33%	12%	11%		
May 29 - Jun 4	0.76	I	2.3	3.0	6.8	6.5	7.0	13	52.9	5.08	6.78	11.24	4.4	4.94	36.0	1.8×10^5	1.7×10^4
		E	2.1	7.7	6.8	6.5	6.9	12	52.0	4.72	6.26	10.78	3.2	4.62	21.5	3.5×10^3	2.2×10^3
		R	9%					8%	2%	7%	8%		27%	6%	40%		
Jun 5 - Jun 11	0.94	I	2.7	2.9	6.6	6.2	6.7	-	30.5	7.18	9.31	10.20	9.4	4.70	51.2	9.1×10^3	4.2×10^3
		E	0.8	6.7	6.6	6.2	6.7	-	24.1	6.35	8.80	10.30	7.4	4.10	35.6	5.3×10^2	1.8×10^2
		R	70%						21%	12%	5%		21%	13%	30%		
Jun 12 - Jun 18	1.12	I	2.9	-	6.5	6.4	7.0	-	49.7	7.91	9.99	12.47	10	6.00	28.8	2.7×10^4	2.4×10^4
		E	0.8	-	6.5	6.3	7.0	-	50.2	6.83	10.14	12.80	9.30	5.66	31.9	1.0×10^4	4.0×10^3
		R	72%							14%			9%	6%	11%		
Jun 19 - Jun 25		I															
		E		no analyses run													
		R															

APPENDIX F (CONTINUED)

Period	Flow	Sample	Turbidity	D.O.	pH	pH	pH	BOD$_5$	COD	NH$_3$-N	TKN	NO$_2$NO$_3$-N	TSS	Total P	Alk.	Coliform - MPN		
	MGD	Point*	NTU	mg/l	Med.	Min.	Max.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	Total #/100 ml	Fecal #/100 ml	
1977 June 26-July 2	1.11	I																
		E																no analyses
		R																run
July 3-July 9	1.05	I	2.3	3.0	7.0	6.9	7.1	---	46.9	18.13	16.90	10.85	12	5.09	94.5	7.0x10^4	1.4x10^3	
		E	3.0	5.3	7.0	6.9	7.1	---	42.5	15.61	14.50	---	---	4.53	79.3	8.0x10^4	6.2x10^3	
		R	-30%						9%	14%	14%			11%	16%			
July 10-July 16	0.92	I	3.9	1.7	7.2	7.0	7.2	36	54.2	17.03	22.93	10.40	8.7	5.61	93.3	9.2x10^5	3.8x10^4	no O$_3$
		E	3.7	4.0	7.2	7.0	7.2	30	60.1	17.91	19.70	9.24	84	5.33	89.2	9.2x10^4	2.4x10^4	
		R	5%					17%	11%		14%			5%	4%			
July 17-July 23	0.98	I	2.0	2.0	7.1	6.9	7.1	33	48.0	11.21	14.00	12.33	2.4	4.79	62.5	2.4x10^4	2.1x10^4	no O$_3$
		E	3.1	5.1	7.1	7.0	7.1	28	39.2	10.11	11.64	12.50	4.0	4.27	50.4	9.2x10^4	9.2x10^4	
		R	6%					15%	18%	10%	17%			11%	19%			
July 24-July 30	1.02	I	2.3	2.4	7.1	6.9	7.2	28	43.2	14.68	17.24	6.46	7.4	5.20	95.6	3.3x10^5	5.7x10^4	MF no MPN's run,
		E	1.9	2.6	6.9	7.1	7.1	37	167	17.74	23.31	3.90	92	5.78	93.9	---	---	no ozone
		R	18%												2%			
July 31-Aug.6	1.12	I	3.2	2.3	7.1	6.8	7.2	56	60.7	18.89	22.84	8.66	20	5.62	105	---	---	
		E	3.4	5.8	7.1	7.0	7.2	105	124	18.42	24.91	5.58	18	7.13	108	---	---	
		R	-6%							2%	9%		10%		2%			
Aug.7-Aug.13	0.93	I	2.4	2.2	7.1	6.8	7.2	27	40.9	16.06	18.62	12.99	2.7	5.43	79.0	---	---	
		E	2.5	5.9	6.9	6.7	7.1	35	35.8	14.93	16.33	12.36	2.6	5.06	78.0	≥2.4x10^3	≥2.4x10^3	
		R	-4%						12%	7%	12%		3%	6%	1%			
Aug.14-Aug.20	1.03	I	3.1	2.1	6.9	6.8	7.1	41	37.5	10.26	12.20	12.62	3.3	5.01	84.0	1.4x10^5	2.2x10^4	
		E	5.1	5.7	7.0	6.7	7.1	77	39.5	9.38	11.62	12.15	8.0	4.78	39.9	≥2.4x10^4	2.8x10^3	
		R	-64%							8%	4%			4%	52%			
Aug.21-Aug.27	0.77	I	1.3	3.0	6.8	6.2	7.1	43	52.6	11.28	12.50	21.70	3.2	4.29	55.0	2.4x10^4	3.6x10^3	
		E	2.3	5.6	6.9	6.2	7.0	34	48.2	10.46	10.73	24.10	1.8	3.89	64.2	2.7x10^4	1.2x10^3	
		R	-76%					21%	8%	7%	14%		43%	9%				
Aug.28-Sept.3	0.49	I	1.2	2.9	6.0	5.6	6.8	14	40.8	8.99	8.43	21.99	3.6	6.65	25.5	5.0x10^2	5.0x10^2	
		E	1.2	7.0	6.2	5.8	6.8	26	49.7	8.15	9.51	20.11	6.0	6.50	23.8	2.4x10^2	1.4x10^2	
		R	0							9%				2%	6%			

APPENDIX F (CONTINUED)

																Coliform - MPN	
Period	Flow	Sample Point*	Turbidity	D.O.	pH	pH	pH	BOD$_5$	COD	NH$_3$-N	TKN	NO$_2$NO$_3$-N	TSS	Total P	Alk.	Total	Fecal
	MGD		NTU	mg/1	Med.	Min.	Max.	mg/1	mg/1	mg/1	mg/1	mg/1	mg/1	mg/1	mg/1	#/100 ml	#/100 ml
1977 Sept. 4-Sept 10	0.54	I	1.7	4.8	6.5	5.4	6.9	5.2	36.8	0.60	2.20	20.41	3.8	5.12	8.4	$2.0x10^4$	$8.0x10^3$
		E	1.5	7.1	6.6	6.0	6.8	4.6	31.8	0.41	1.25	17.97	5.3	4.70	12.6	$2.3x10^4$	$4.2x10^3$
		R	11%					11%	14%	32%	43%			8%			
Sept. 11-Sept 17	0.56	I	1.2	5.2	6.6	6.4	6.8	3.0	37.0	0.06	1.13	12.62	7.0	4.50	24.2	-	No 03 ru
		E	1.2	5.0	6.6	6.4	6.8	3.8	32.5	0.07	1.19	12.44	6.8	4.13	25.8	-	-
		R	0%						12%				2%	8%	7%		
Sept. 18-Sept. 24	0.58	I	1.9	4.3	6.5	6.3	7.0	-	27.7	0.10	3.95	-	3.3	4.00	28.4	$5.9x10^2$	51
		E	1.6	5.3	6.7	6.3	6.9	6.7	36.8	1.86	3.46	11.44	4.1	3.85	30.0	99	24
		R	15%								12%			4%			
Sept. 25-Oct. 1	0.49	I	3.8	2.8	6.9	6.8	7.0	27	71.6	8.68	11.50	11.08	41	9.16	-		No 03 ru
		E	3.3	4.5	6.9	6.8	7.0	24	65.8	8.35	10.79	11.58	24	7.72	55.1		
		R	13%					11%	8%	4%	6%		41%	16%			
Oct. 2-Oct. 8	0.40	I	2.2	4.1	6.6	6.2	7.0	10	36.1	0.16	1.18	17.55	3.2	4.78	-	-	-
		E	1.7	6.9	6.5	4.6	7.1	5.1	31.6	1.52	3.29	11.36	5.1	4.11	32.1	-	-
		R	22%					49%	12%				-59%	14%			
Oct. 9-Oct. 15	0.40	I	3.3	5.1	6.5	6.2	6.9	5.5	28.4	0.47	2.99	16.06	15	7.28	9.1	-	-
		E	2.3	6.9	6.6	6.2	7.0	5.5	27.7	0.34	2.91	13.53	5.2	5.97	13.5	-	33
		R	30%					0%	2%	28%	3%		65%	18%			
Oct. 16-Oct. 22	0.36	I	1.1	5.1	6.3	6.1	6.9	3.2	29.6	0.06	1.12	17.96	3.4	4.82	9.0	$1.6x10^4$	$2.8x10^2$
		E	0.9	7.3	6.3	6.0	7.0	3.4	27.7	0.04	0.65	15.87	3.2	4.31	9.5	59	37
		R	18%						6%	33%	42%		6%	10%			
Oct. 23-Oct. 29	0.37	I	4.1	6.4	6.3	6.0	6.8	5.2	41.0	0.01	2.47	17.58	10	5.04	7.6	$1.7x10^4$	$6.1x10^3$
		E	3.4	8.3	6.2	6.2	6.3	8.2	37.6	0.02	2.24	15.85	7.6	4.63	9.8	$1.6x10^2$	6.8x10
		R	17%						8%		9%		24%	8%			
Oct. 30-Nov. 5	0.36	I	4.0	5.6	6.6	5.6	7.0	7.4	42.9	0.03	2.45	14.66	9.2	4.68	17.1	$1.6x10^4$	$1.5x10^3$
		E	3.0	8.0	6.5	5.9	6.9	6.1	48.3	0.04	2.86	13.21	13	4.56	18.3	$2.4x10^2$	92
		R	25%					18%	13%					2%			
Nov. 6-Nov. 12	0.27	I	2.0	5.7	6.1	6.0	6.3	8.2	31.1	0.55	1.99	20.56	7.3	6.38	4.8	$3.2x10^3$	$5.7x10^2$
		E	2.0	8.2	6.2	6.1	6.4	4.7	29.6	0.06	1.44	18.94	6.3	5.23	10.3	$2.1x10^2$	22
		R	0%					43%	5%	89%	28%		14%	18%			

APPENDIX F (CONTINUED)

															Coliform - MPN	
Period	Flow	Sample Point*	Turbidity	D.O.	pH	pH	pH	BOD$_5$	COD	NH$_3$-N	TKN	NO$_2$NO$_3$-N	TSS	Total P	Alk.	Total	Fecal
	MGD		NTU	mg/l	Med.	Min.	Max.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	#/100 ml	#/100 ml
1977 Nov. 13-Nov. 19	0.31	I	6.5	5.8	6.6	6.5	6.8	9.2	73.3	0.15	5.04	16.68	23	8.26	10.9	5.6×10^{3}	5.6×10^{3}
		E	5.9	7.9	6.6	6.4	6.7	5.9	64.6	0.16	5.40	15.38	20	7.65	14.7	90	28
		R	9%					36%	12%	7%	7%		13%	7%	35%		
Nov. 20-Nov. 26	0.32	I	1.9	6.9	6.3	5.4	6.4	4.5	101	0.27	2.06	17.20	4.0	4.90	10.4	4.3×10^{4}	1.2×10^{4}
		E	1.3	8.7	6.1	5.5	6.4	3.8	89.0	0.05	1.20	16.38	2.9	4.56	12.4	33	24
		R	50%					16%	12%	81%	42%		27%	7%			
Nov. 27-Dec. 3	0.30	I	1.6	6.6	6.3	5.8	6.5	4.5	26.5	0.85	2.14	17.03	5.3	5.07	8.8	5.7×10^{3}	3.0×10^{3}
		E	1.4	8.9	6.3	6.2	6.9	4.5	25.4	0.80	0.91	15.94	3.8	4.47	8.2	7.7×10^{1}	1.0×10^{1}
		R	50%					0%	4%	6%	57%		28%	12%	7%		
Dec. 4-Dec. 10	0.31	I	2.0	6.7	6.6	6.2	7.2	1.8	28.7	0.29	2.07	15.46	4.5	4.43	3.4	2.9×10^{4}	4.2×10^{3}
		E	1.5	9.2	6.6	6.2	7.1	5.0	24.2	0.29	1.58	13.41	3.9	3.98	2.9	80	3
		R	25%						15%	0%	23%		13%	10%	14%		
Dec. 11-Dec. 17	0.31	I	1.3	7.2	6.7	6.5	6.9	2.6	29.6	0.06	1.44	14.40	3.4	4.[illegible]	9.4	no ozone	
		E	1.1	8.5	6.4	6.6	6.7	5.9	27.7	0.07	1.07	12.73	2.7	[illegible].08	13.6		
		R	15%						6%		25%		20%	7%	46%		
Dec. 18-Dec. 24	0.29	I	2.0	6.8	6.4	6.3	6.9	1.8	22.6	0.78	1.68	13.76	4.7	5.25	13.0	no ozone	
		E	1.6	8.5	6.4	6.2	6.8	0.8	21.7	0.64	1.54	13.43	4.0	4.82	11.3		
		R	20%					55%	3%	17%	8%		14%	8%	13%		
Dec. 25-Dec. 31	0.48	I	2.3	6.2	7.4	7.0	7.5	8.0	37.2	12.88	14.07	11.45	5.5	7.50	45.0	2.0×10^{5}	1.8×10^{4}
		E	2.1	8.5	7.2	7.0	7.5	8.5	32.4	12.30	13.36	10.82	5.0	6.54	65.1	3.2×10^{1}	4
		R	8%						12%	4%	5%		10%	12%			
1978 Jan. 1-Jan. 7	0.42	I	2.0	5.4	7.2	7.1	7.3	0.6	30.5	11.88	13.77	7.31	4.6	7.30	81.6	5.4×10^{4}	7.0×10^{3}
		E	1.8	8.7	7.2	7.1	7.3	7.5	31.9	12.16	13.38	6.82	4.1	8.23	79.4	1.1×10^{2}	7
		R	10%								2%		10%		2%		
Jan. 8-Jan. 14	0.38	I	1.6	4.8	7.1	6.9	7.3	3.8	34.1	9.43	10.95	7.14	2.7	4.82	67.0	3.8×10^{4}	1.6×10^{3}
		E	1.4	8.7	7.2	6.9	7.5	4.2	31.4	8.89	10.03	5.83	2.2	4.61	65.6	2.0×10^{2}	1.4×10^{2}
		R	12%						7%	5%	8%		18%	4%	2%		
Jan. 15-Jan. 21	0.26	I	1.0	4.7	7.0	6.9	7.2	3.8	17.3	8.84	10.44	8.53	2.6	4.55	61.4	1.2×10^{4}	2.2×10^{3}
		E	0.8	7.6	7.0	6.9	7.2	3.1	16.7	8.16	9.88	7.40	2.4	3.33	62.7	1.2×10^{2}	8.6×10^{1}
		R	26%					18%	2%	7%	5%		7%	26%			

APPENDIX F (CONTINUED)

																Coliform - MPN	
Period	Flow	Sample Point*	Turbidity	D.O.	pH	pH	pH	BOD$_5$	COD	NH$_3$-N	TKN	NO$_2$NO$_3$-N	TSS	Total P	Alk.	Total	Fecal
	MGD		NTU	mg/1	Med.	Min.	Max.	mg/1	mg/1	mg/1	mg/1	mg/1	mg/1	mg/1	mg/1	#/100 ml	#/100 ml
1978		I	1.7	5.8	7.2	6.9	7.3	5.4	23.9	10.77	11.97	6.00	4.2	4.74	76.8	---	---
Jan.22-Jan.28	0.35	E	1.5	6.9	7.2	7.0	7.4	5.0	26.5	10.05	11.55	7.13	3.8	4.67	72.6	$7.9x10^3$	$3.3x10^3$
		R	12%					8%		6%	3%		9%	1%	5%		
Jan.29-Feb.4	0.40	I	1.7	5.4	7.2	7.1	7.3	6.7	30.4	8.91	11.41	6.55	3.5	3.94	66.1	No Ozone	
		E	1.6	7.9	7.2	7.1	7.3	8.8	26.5	9.27	10.63	6.76	8.9	4.23	64.6		
		R	6%						12%		6%				2%		
Feb.5-Feb.11	0.37	I	2.1	6.1	7.1	6.9	7.1	12	39.2	10.52	12.93	5.36	4.9	5.41	64.5	No Ozone	
		E	1.9	8.6	7.0	7.0	7.1	9.2	37.3	9.71	12.46	5.72	5.2	5.48	65.9		
		R	10%					23%	4%	7%	3%						
Feb.12-Feb.18	0.44	I	2.2	6.1	7.1	6.9	7.2	6.6	31.2	9.70	12.06	4.72	4.6	4.56	67.8	No Ozone	
		E	1.8	6.5	7.0	6.9	7.1	5.5	35.3	9.42	12.95	4.78	3.9	4.29	63.7		
		R	18%					16%		2%			15%	6%	6%		
Feb.19-Feb.25	0.46	I	2.3	5.1	7.2	7.0	7.2	11	23.7	11.45	13.66	4.12	6.6	4.89	67.8	$7.0x10^4$	$3.4x10^3$
		E	2.0	4.7	7.1	7.0	7.2	11	27.6	11.66	13.24	4.36	4.5	4.82	76.7	$1.5x10^2$	32
		R	15%					0%			3%		32%	1%			
Feb.26-Mar.4	0.41	I	1.4	4.6	7.0	6.8	7.1	5.6	25.6	9.52	11.89	5.70	3.6	5.34	65.1	$7.1x10^4$	$5.9x10^4$
		E	1.3	5.3	7.0	6.8	7.0	6.9	19.6	8.94	10.76	5.52	3.0	5.05	63.1	$3.0x10^2$	$2.1x10^2$
		R	7%						23%	6%	10%		20%	5%	3%		
Mar.5-Mar.11	0.43	I	1.4	3.9	6.9	6.8	7.1	5.2	43.0	8.93	11.58	7.21	5.6	11.96	70.9	No Ozone	
		E	1.2	3.7	6.9	6.8	7.0	7.7	42.0	8.62	11.84	7.07	3.9	11.80	65.8		
		R	14%						2%	3%			30%	1%	7%		
Mar.12-Mar.18	0.44	I	1.2	4.5	6.9	6.8	7.2	3.8	27.8	7.00	8.68	6.34	3.5	4.69	52.3	No Ozone	
		E	1.1	4.6	6.9	6.9	7.1	4.7	26.7	6.76	8.61	6.09	3.1	4.31	56.1		
		R	8%						4%	3%	1%		11%	8%			
Mar.15-Mar.25	0.54	I	2.0	3.8	7.1	7.0	7.1	16	36.6	10.42	12.74	5.79	6.2	4.89	75.6	No Ozone	
		E	2.1	4.4	7.1	6.7	7.2	17	44.4	10.23	12.10	5.25	5.7	4.52	72.1		
		R								2%	5%		8%	8%	5%		
Mar.26-Apr.1	0.48	I	1.8	3.9	6.9	6.9	7.0	10	36.7	10.37	12.33	7.57	2.8	4.21	49.6	No Ozone	
		E	1.6	4.8	6.9	6.8	7.0	9	37.5	9.48	12.04	7.36	3.9	4.14	59.6		
		R	11%					10%		9%	2%			2%			

APPENDIX F (CONTINUED)

Period	Flow	Sample	Turbidity	D.O.	pH	pH	pH	BOD$_5$	COD	NH$_3$-N	TKN	NO$_2$NO$_3$-N	TSS	Total P	Alk.	Coliform - MPN	
																Total	Fecal
	MGD	Point *	NTU	mg/l	Med.	Min.	Max.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	#/100 ml	#/100 ml
1978 April 2 - 8	0.57	I	1.2	2.9	6.8	6.4	6.9	14	31.7	6.51	8.09	6.64	2.8	5.85	52.0	$8.4x10^3$	$7.8x10^3$
		E	1.2	3.2	6.8	6.5	7.1	18	31.7	6.32	7.85	6.17	2.5	5.86	55.5	$1.6x10^4$	$2.2x10^3$
		R							0%	3%	3%		11%	0%	7%		
April 9 - 15	0.50	I	1.1	2.7	6.7	6.6	6.9	12	30.1	5.11	5.98	6.33	3.1	4.33	61.8		
		E	1.1	4.0	6.9	6.6	7.0	10	31.7	4.40	6.50	6.18	4.1	----	55.1	No Ozone	
		R						17%		14%					11%		
April 16 - 22	0.39	I	1.2	2.3	6.9	6.8	6.9	24	39.9	6.01	7.40	5.97	2.2	5.78	62.3	$1.7x10^3$	$7.2x10^2$
		E	1.0	8.2	7.0	6.8	7.2	18	37.0	5.81	6.72	5.76	2.2	5.01	51.4	9	6
		R						25%	7%	3%	9%		0%	13%	17%		
April 23 - 29	0.44	I	1.6	2.8	7.1	6.8	7.2	22	40.9	5.24	6.45	3.85	4.8	6.53	72.4	$2.7x10^4$	$1.5x10^4$
		E	1.4	7.2	7.1	6.8	7.2	12	32.4	5.15	6.08	3.81	4.3	5.86	60.7	$1.9x10^1$	5
		R						45%	21%	2%	6%		10%	10%	16%		
April 30 - May 6	0.55	I	1.8	1.4	7.1	6.9	7.3	14	30.2	4.38	5.89	4.35	3.6	8.58	63.9		
		E	1.6	6.1	7.0	6.9	7.1	10	25.4	4.03	5.46	4.26	2.5	6.63	74.2	No Ozone	
		R						28%	16%	8%	7%		30%	23%			
May 7 - 13	0.89	I	1.7	1.2	6.9	6.7	7.1	17	33.7	4.92	6.29	3.03	1.7	----	65.1		
		E	1.4	6.2	6.9	6.7	7.1	18	29.7	4.03	5.60	3.83	1.6	3.35	65.1	No Ozone	
		R							12%	18%	11%		6%		0%		
May 14 - 20	1.10	I	1.0	0.9	6.8	6.7	6.9	5.0	27.2	4.51	6.64	4.65	2.8	4.79	69.3		
		E	0.9	7.1	6.9	6.8	6.9	6.6	31.0	3.76	5.63	4.95	1.0	4.26	68.3	No Ozone	
		R								17%	15%		64%	11%	1%		
May 21 - 27	0.92	I	1.4	1.1	7.0	6.9	7.1	14	34.0	3.02	4.35	6.00	2.6	2.15	63.8	$3.4x10^3$	$1.4x10^3$
		E	1.2	8.0	7.0	6.8	7.1	15	31.0	2.70	4.09	6.07	5.2	2.44	59.4	$1.7x10^1$	$1.3x10^1$
		R							9%	10%	6%				7%		
May 28 - June 3	0.73	I	1.8	2.1	7.0	6.9	7.3	18	43.4	7.32	9.68	3.99	3.2	2.91	86.1	$1.3x10^4$	$7.0x10^2$
		E	1.5	7.5	7.1	6.9	7.3	13	41.9	7.05	8.65	3.95	3.0	3.14	88.2	$7.9x10^1$	$1.3x10^1$
		R						28%	3%	4%	11%		6%				
June 4 - 10	0.74	I	2.1	1.4	7.0	6.9	7.3	18	44.1	7.22	8.23	4.86	4.9	----	52.5		
		E	2.0	6.4	7.2	7.0	7.4	18	37.2	6.11	7.88	4.96	3.7	3.78	32.5	No Ozone	
		R						0%	16%	15%	4%		24%		38%		

APPENDIX F (CONTINUED)

																Coliform - MPN	
Period	Flow MGD	Sample Point*	Turbidity NTU	D.O. mg/l	pH Med.	pH Min.	pH Max.	BOD$_5$ mg/l	COD mg/l	NH_3-N mg/l	TKN mg/l	NO_2NO_3-N mg/l	TSS mg/l	Total P mg/l	Alk. mg/l	Total #/100 ml	Fecal #/100 ml
1978 June 11 - 17	0.92	I	2.8	1.6	7.2	7.0	7.7	---	51.8	7.72	--	0.88	--	---	--		
		E	2.8	5.6	7.1	7.0	7.4	30	--	7.62	--	1.59	11	4.00	--	No Ozone	
		R								1%							
June 18 - 24	0.76	I	2.0	2.7	6.9	6.7	7.1	--	--	10.88	--	6.66	--	---	--		
		E	1.8	7.7	7.0	6.8	7.1	16	--	10.84	--	6.88	--	4.64	--	No Ozone	
		R								0%							
June 25 - July 1	0.76	I	2.1	2.0	--	---	---	35	50.5	--	--	--	2.2	---	--		
		E	1.9	6.9	6.9	6.6	7.1	46	--	12.71	--	--	3.5	5.23	--	No Ozone	
		R															
July 2 - 8	0.70	I	2.5	--	--	---	---	--	--	--	--	--	--	---	--		
		E	2.1	--	7.0	6.9	7.1	30	--	18.60	--	--	5.3	5.68	--	No Ozone	
		R															
July 9 - 15	0.70	I	2.0	--	---	---	---	--	--	--	--	--	--	---	--		
		E	2.3	--	6.9	6.9	7.0	21	--	9.39	--	--	2.6	5.58	--	No Ozone	
		R															
July 16 - 22	0.74	I	1.7	--	---	---	---	--	--	--	--	--	--	---	--		
		E	1.5	--	---	---	---	46	--	14.54	--	--	2.2	5.98	--	No Ozone	
		R															
July 23 - 29	0.76	I	1.8	--	---	---	---	--	--	--	--	--	--	---	--		
		E	1.7	6.1	6.8	6.8	7.0	48	--	13.07	--	--	4.2	8.46	--	No Ozone	
		R															
		I															
		E															
		R															
		I															
		E															
		R															
		I															
		E															
		R															

APPENDIX G

TABLE G-1. PROCEDURE FOR OZONE AIR CONCENTRATION TESTING AT THE UPPER THOMPSON SANITATION DISTRICT

1. Set ozonator at desired amperage setting. Record generator information on data sheet (See Table A-2).
2. Check Dasibi Meter zero, span and control and sample frequency readings and adjust if necessary.
3. Prepare wet test chemistry equipment (See Figure A-1).
   a. Add 400 ml of 2% KI Solution to each of two 500 ml gas washing bottles (Note: Fritted glass diffuser was not used on ozone-air inlet tube).
   b. Connect gas washing bottles in series and connect ozone supply line and wet test meter.
   c. Level wet test meter and adjust water level in the meter.
4. Open vent valve and vent test line for two (2) minutes.
5. Read and record three consecutive Dasibi Meter readings.
6. Set two-way valve to direct ozone-air gas flow to the gas washing bottles and open flow control valve to full open (metering valve set for 2 liters/minute).
7. Run approximately 4.5 liters of gas flow through the bottles and record field data information on data sheet (See Table A-2).
8. Take gas washing bottles to laboratory immediately and have another person read and record three more Dasibi Meter readings.
9. Quantitatively transfer liquid from gas washing bottles to two separate 1 liter erlynmeyer flasks. Rinse tubes and bottles at least three times.
10. Immediately add 10 ml of 2N Sulfuric Acid (H_2SO_4).
11. Read initial buret volume which contains 0.1N sodium thiosulfate solution ($Na_2S_2O_3$). Note: Standardize $Na_2S_2O_3$ using the dichromate method. (*Standard Methods* Ed. 14, pp. 316).
12. Quickly titrate the darker of the 2 flasks to a pale yellow color with the $Na_2S_2O_3$).
13. Add 5 ml starch indicator (See *Standard Methods* Ed. 14, pp. 317 for starch preparation) and carefully titrate by drop until clear.
14. Add 5 ml starch indicator to second flask and again carefully titrate dropwise until clear.
15. Record final volume buret reading and determine total volume of titrant used. Record on data sheet.
16. Complete calculations on data sheet (See Table A-2).

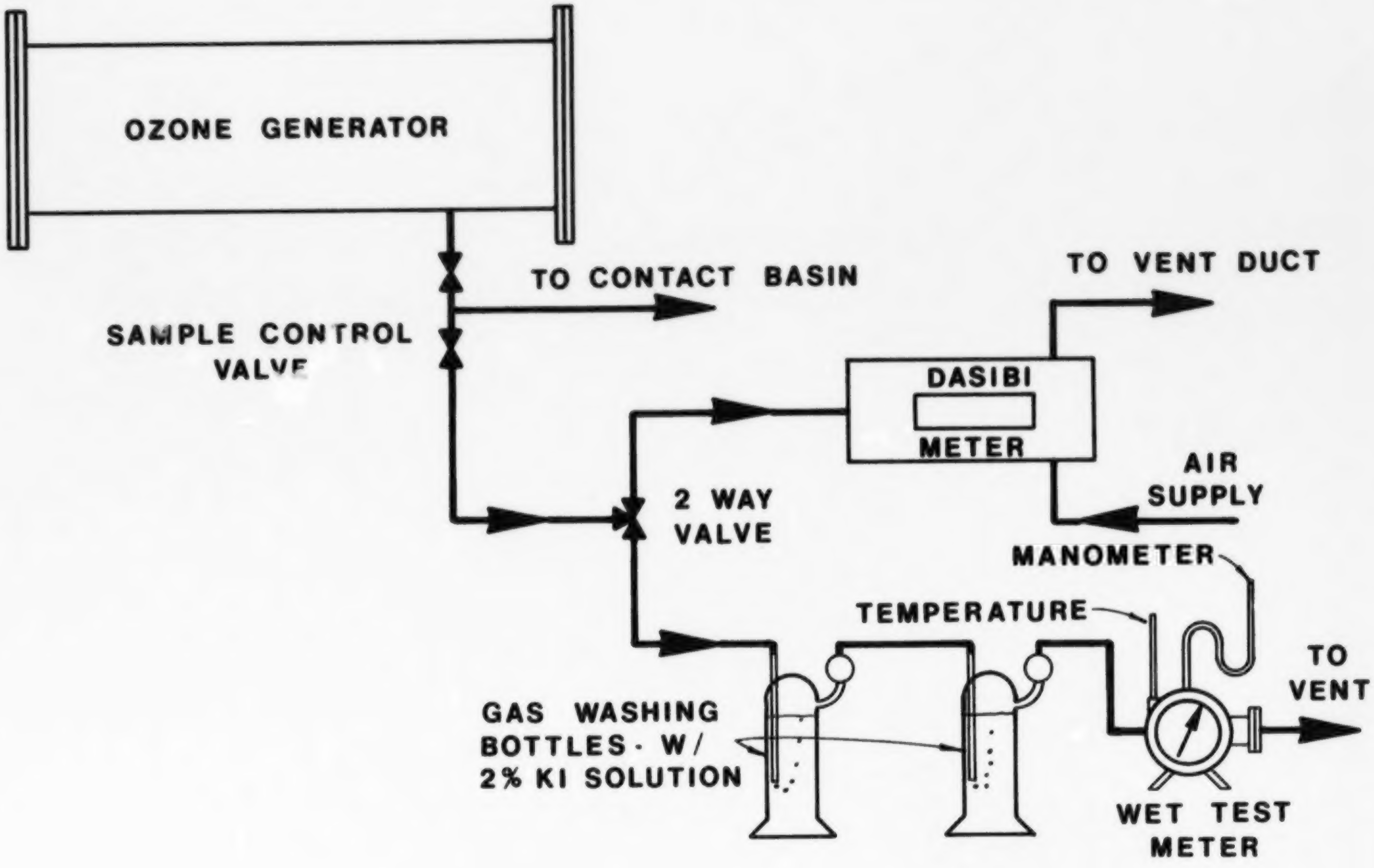

OZONE GENERATOR
TO CONTACT BASIN
SAMPLE CONTROL VALVE
TO VENT DUCT
DASIBI METER
AIR SUPPLY
2 WAY VALVE
MANOMETER
TEMPERATURE
TO VENT
GAS WASHING BOTTLES W/ 2% KI SOLUTION
WET TEST METER

Figure G-1. Ozone Production Monitoring.

TABLE G-1. OZONE PRODUCTION DATA RECORDING SHEET

OZONE SYSTEM PERFORMANCE DATA

OZONE UTILIZATION AND TRANSFER CALCULATIONS

Date ________________ Time of Analysis ________________

FIELD INFORMATION

Vent Gas: Flow ________ scfm (25°C) (see graph)

Wet Test Meter: Volume ________ L Temperature ________ °F Manometer ________ in. H_2O (suction is negative)
Water Vapor Pressure ________ in. H_2O (see graph)

LAB INFORMATION

Wet Test Meter: Titration ________ mls N of $Na_2S_2O_3$ ________ mole eq/L

Ozone Residual: Titration ________ mls N of $Na_2S_2O_3$ ________ mole eq/L

CALCULATIONS

Ozone Concentration in Off Gas:

Calculate weight of ozone trapped in KI solution.

$$WT = \left(\frac{\text{N mole eq}}{\text{L}}\right)(\text{Titration ml})\left(\frac{24\ \text{gm}\ O_3}{\text{mole eq}}\right)\left(\frac{1.0\ \text{L}\cdot\text{mg}}{\text{gm}\cdot\text{ml}}\right) = (\underline{\hspace{3em}}\ \text{mole eq/L})(\underline{\hspace{3em}}\ \text{ml})\left(\frac{24\ \text{gm}\ O_3}{\text{mole eq}}\right)\left(\frac{1.0\ \text{L mg}}{\text{ml}\cdot\text{gm}}\right) = \underline{\hspace{4em}}\ \text{mg}$$

Calculate volume of gas that paaed through wet test meter.

$$V_2 = (V_1)\left(\frac{P_1}{P_2}\right)\left(\frac{T_2}{T_1}\right) = (\underline{\hspace{3em}}\ \text{L})\left(\frac{\underline{\hspace{3em}}\ \text{in. } H_2O}{406.8\ \text{in. } H_2O}\right)\left(\frac{536.6\,^{\circ}\text{R}}{\underline{\hspace{3em}}\,^{\circ}\text{R}}\right) = \underline{\hspace{5em}}\ \text{L}$$

Where: V_1 = Actual volume L

P_2 = Standard Pressure = 406.8 in H_2O

P_1 = Adjusted Pressure = (Plant Atmospheric Pressure (7460' of 314 in. H_2O) – (water vapor pressure) + (wet test manometer pressure – Note: suction is negative). P_1 = ________ – ________ + ________ = ________ in. H_2O

T_2 = Standard Temperature (absolute) = 77°F + 459.6 = 536.6°R

T_1 = Actual Temperature (absolute) ________ °F + 459.6 = ________ °R

Calculate ozone concentration in off gas.

$$\text{mg/L air} = (\underline{\hspace{3em}}\ \text{mg})\left(\frac{1}{\underline{\hspace{3em}}\ \text{L}}\right) = \underline{\hspace{3em}}\ \text{mg/L air}$$

$$\text{ppm/vol} = (\underline{\hspace{3em}}\ \text{mg/L air})(1{,}000{,}000)\left(\frac{1}{1959}\right) = \underline{\hspace{3em}}\ \text{ppm/vol}\ (25^{\circ}\text{C})$$

Residual Ozone Concentration:

Calculate weight of ozone trapped in KI solution.

$$WT = \left(\frac{\text{N mole eq}}{\text{L}}\right)(\text{Titration ml})\left(\frac{24\ \text{gm}\ O_3}{\text{mole eq}}\right)\left(\frac{1.0\ \text{L}\cdot\text{mg}}{\text{gm}\cdot\text{ml}}\right) = \left(\frac{\underline{\hspace{3em}}\ \text{mole eq}}{\text{L}}\right)(\underline{\hspace{3em}}\ \text{ml})\left(\frac{24\ \text{gm}\ O_3}{\text{mole eq}}\right)\left(\frac{1.0\ \text{L}\cdot\text{mg}}{\text{gm}\cdot\text{ml}}\right) = \underline{\hspace{4em}}\ \text{mg}$$

Calculate Residual Ozone Concentration.

$$\text{mg/L } H_2O = (\underline{\hspace{3em}}\ \text{mg})\left(\frac{1}{\underline{\hspace{3em}}\ \text{ml of sample}}\right)\left(\frac{1000\ \text{ml}}{\text{L}}\right) = \underline{\hspace{3em}}\ \text{mg/L } H_2O$$

Ozone Lost in Vent:

Calculate ozone lost in vent.

$$\text{lbs/day} = (\underline{\hspace{3em}}\ \text{ft}^3/\text{min})(\underline{\hspace{3em}}\ \text{mg/L air})(28.32\ \text{L/ft}^3)\left(\frac{1}{453{,}400}\ \frac{\text{lbs}}{\text{day}}\right)(1440\ \text{min/day}) = \underline{\hspace{4em}}\ \text{lbs/day}$$

Residual Ozone:

Calculate amount of residual ozone in the water.

$$\text{lbs/day} = (\underline{\hspace{3em}}\ \text{mg/L } H_2O)(\underline{\hspace{3em}}\ \text{mgd})(8.34\ \text{lbs/gal}) = \underline{\hspace{4em}}\ \text{lbs/day}$$

Ozone Transfer:

$$\text{Percent Ozone Transfer} = \frac{(\text{ozone supply rate (lbs/day)} - \text{ozone lost in vent (lbs/day)})\ (100)}{\text{ozone supply rate (lbs/day)}}$$

$$= \frac{\underline{\hspace{3em}}\ (\text{lbs/day}) - \underline{\hspace{3em}}\ (\text{lbs/day})\ (100)}{\underline{\hspace{4em}}\ (\text{lbs/day})} = \underline{\hspace{4em}}\ \%$$

Effective Ozone Dosage:

Concentration of Effective Ozone Dosage = (Percent Transfer efficiency) (applied ozone dosage) = (________ %) (________ mg/L H_2O)
= ____________ mg/L H_2O

(Continued)

TABLE G-2 (CONT). OZONE PRODUCTION DATA RECORDING SHEET

OZONE SYSTEM PERFORMANCE DATA

GENERATOR OUTPUT, APPLIED OZONE DOSAGE, DISINFECTION RESULTS, POWER REQUIREMENTS (Continued)

Calculate Ozone supply rate.

$$\text{lbs/day} = (\_\_\_\_\ \text{ft}^3/\text{min})\ (\_\_\_\_\ \text{mg/L air})\ (28.32\ \text{L/ft}^3)\ \left(\frac{1}{453{,}400}\ \frac{\text{lbs}}{\text{mg}}\right)\ (1440\ \text{min/day}) = \_\_\_\_\ \text{lbs/day}$$

Applied Ozone Dosage:

$$\text{mg/L } H_2O = (\_\_\_\_\ \text{lbs/day})\ \left(\frac{1}{\_\_\_\_\ \text{mgd}}\right)\ \left(\frac{1}{8.34}\ \frac{\text{gal}}{\text{lb}}\right) = \_\_\_\_\ \text{mg/L } H_2O$$

DISINFECTION RESULTS

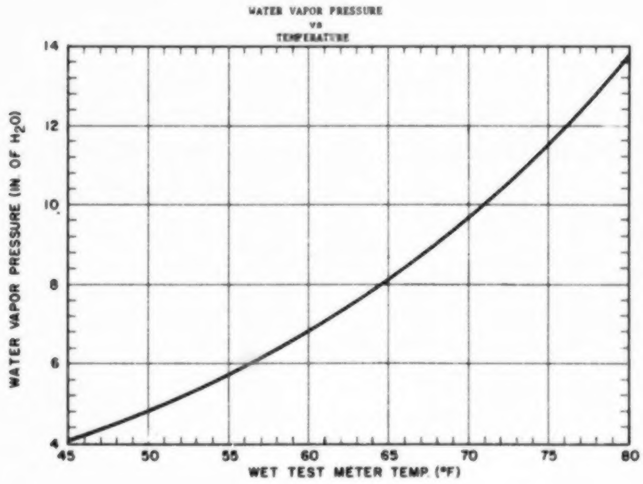
Values expressed in number of coliforms/100 ml

	O_3 Basin Influent		O_3 Basin Effluent	
	MF	MPN	MF	MPN
Total	____	____	____	____
Fecal	____	____	____	____

Calculate Power Utilization

$$\text{KWH/lb } O_3 = \text{Power Utilization} = \frac{\dfrac{\left(\frac{\text{Revs}}{\text{Sec}}\right)(4.8\ \text{watts/sec})\ (86{,}400\ \text{sec/day})\ (40)}{1000\ \text{watt/KW}}}{\text{Ozone Supply Rate (lbs } O_3\text{/day)}}$$

$$= \frac{(\_\_\_\_\ \text{Revs/Sec})\ \left(16{,}588.8\ \frac{\text{KWH/day}}{\text{Revs/sec}}\right)}{\_\_\_\_\ \text{lbs } O_3\text{/day}} = \_\_\_\_\_\_\_\_\ \text{KWH/lb } O_3$$



APPENDIX H

TABLE H-1. PROCEDURE FOR CONTACT BASIN OFF GAS TESTING AT THE UPPER THOMPSON SANITATION DISTRICT

1. Prepare wet test chemistry equipment (See Figure B-1).
    a. Add 400 ml of 2% KI solution to one gas washing bottle.
    b. Connect wash bottle to test line and wet test meter.
    c. Connect vacuum line to wet test meter vent.
    d. Level wet test meter and adjust water level in the meter.
    e. Open vacuum valve until moderate gas flow rate is established.
2. Run approximately 12 liters of gas through the botle and record field information on data sheet (See Table B-2).
3. Take gas washing bottle to laboratory immediately.
4. Quantitatively transfer liquid from gas washing bottle to a 1 liter Erlenmyer flask. Rinse tube and bottle at least 3 times.
5. Immediately add 10 ml of 2N Sulfuric Acid (H_2SO_4).
6. Read initial volume of buret which has been filled with 0.1N sodium thosulfate solution ($Na_2S_2O_3$). Note: Standardize $Na_2S_2O_3$ using the dichromate method. (Standard Methods Ed. 14, pp. 316).
7. Quickly titrate to pale yellow with $Na_2S_2O_3$.
8. Add 5 ml starch indicator (See Standard Methods - Edition 14, pp. 317 for starch preparation) and slowly titrate by drop to a clear end point.
9. Record final volume of buret and determine total volume titrant used. Record information on data sheets (See Table B-2).
10. Complete calculations on data sheet (See Table B-2).

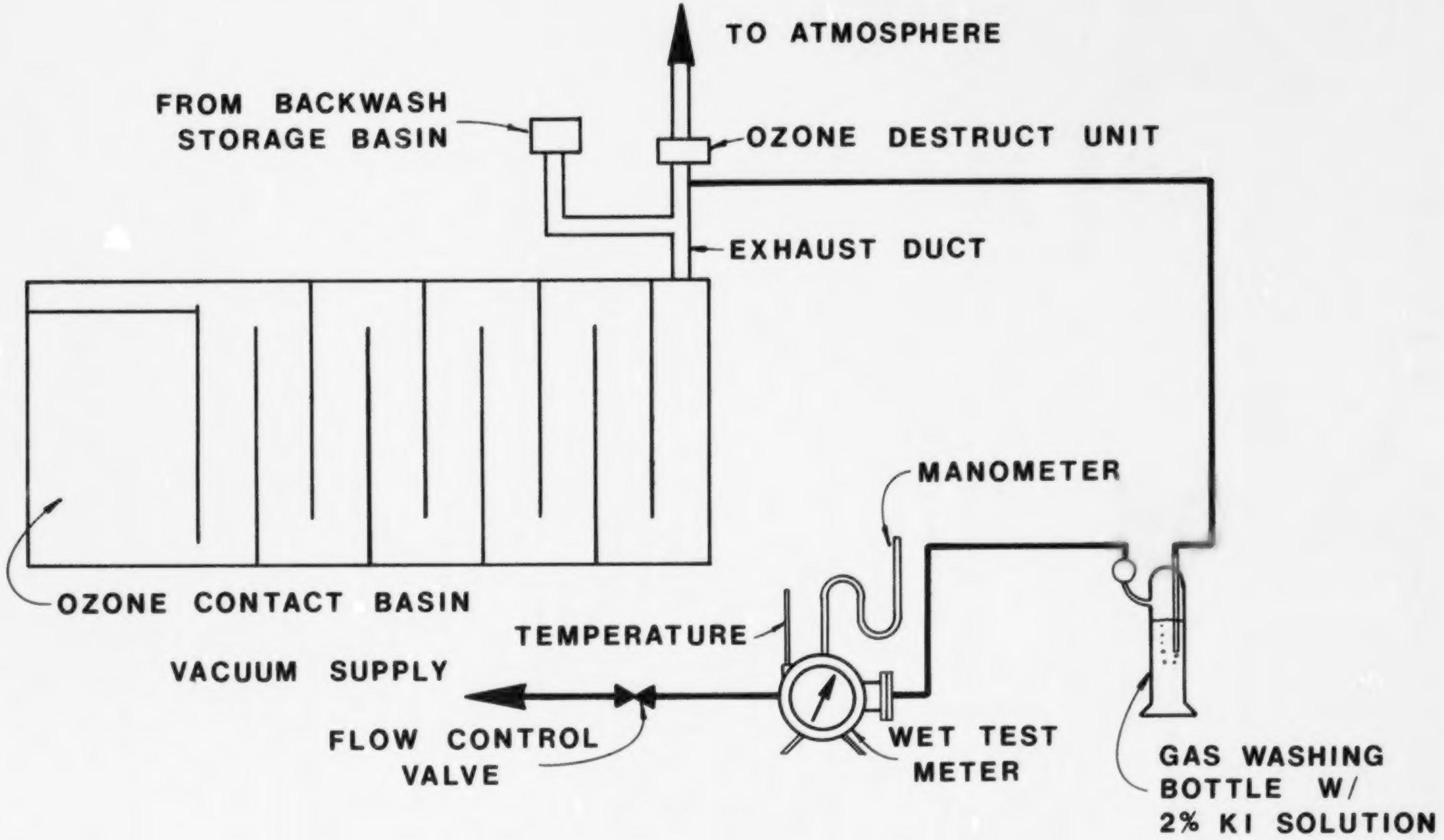

TO ATMOSPHERE
FROM BACKWASH STORAGE BASIN
OZONE DESTRUCT UNIT
EXHAUST DUCT
MANOMETER
OZONE CONTACT BASIN
TEMPERATURE
VACUUM SUPPLY
FLOW CONTROL VALVE
WET TEST METER
GAS WASHING BOTTLE W/ 2% KI SOLUTION

Figure H-1. Contact Basin Off-Gas Monitoring.

TABLE H-2. OZONE OFF-GAS DATA RECORDING SHEET

OZONE SYSTEM PERFORMANCE DATA

GENERATOR OUTPUT, APPLIED OZONE DOSAGE, DISINFECTION RESULTS, POWER REQUIREMENTS

Date ________________ Time of Analysis ________________

FIELD INFORMATION

Generator: No. ________ Voltage ________volts Amperage ________amps Controller Setting ________%

Gas Cooler: Exchanger Temperature ________°F Inlet Temperature ________°F Main Pressure ________psig
Separator Pressure ________psig

Air Compressor: Seal Water Pressure ________psig

Air Pretreatment: Volume ________cfm Pressure ________psig Temperature ________°F Dewpoint (_____°C)

Dasibi Meter: Reading ________ppm/vol Corrected Reading ________ppm/vol

Wet Test Meter: Volume ________L Temperature ________°F Manometer ________in. H_2O (suction is negative)
Water Vapor Pressure ________in. H_2O (see graph)

Heating Tower: On ________ Off ________ **Refrigeration**: On ________ Off ________ **Tower Drying**: Left ______ Right ______

Power Demands: System Amperage
Leg 1 Amperage ________amps
Leg 2 Amperage ________amps
Leg 3 Amperage ________amps

Watt-Hour Meter - Revolutions ________rvs Time ________sec.

LAB INFORMATION

Wet Test Meter: Titration __________mls N of $Na_2S_2O_3$ ________ mole eq/L

DASIBI INFORMATION

Span __________
Inlet Temp. _____°F
Meter Readings:
__________ __________
__________ __________
__________ __________
Average __________

GENERATOR OUTPUT AND APPLIED OZONE DOSAGE CALCULATIONS

Ozone Concentration:

Calculate Weight of ozone trapped in KI Solution.

$$WT = \left(\frac{N\ \text{mole eq}}{L}\right)(\text{Titration ml})\left(\frac{24\ \text{gm}\ O_3}{\text{mole eq}}\right)\left(\frac{1.0\ \text{L}\cdot\text{mg}}{\text{gm}\cdot\text{ml}}\right)$$

$$WT = \left(\frac{\underline{\qquad\qquad}\ \text{mole eq}}{L}\right)(\underline{\qquad}\ \text{ml})\left(\frac{24\ \text{gm}\ O_3}{\text{mole eq}}\right)\left(\frac{1.0\ \text{L}\cdot\text{mg}}{\text{gm}\cdot\text{ml}}\right) = \underline{\qquad}\ \text{mg}$$

Calculate volume of gas that passed through wet test meter.

$$V_2 = (V_1)\left(\frac{P_1}{P_2}\right)\left(\frac{T_2}{T_1}\right) = (\underline{\qquad}\ \text{L})\left(\frac{\underline{\qquad}\ \text{in. } H_2O}{406.8\ \text{in. } H_2O}\right)\left(\frac{536.6^\circ R}{\underline{\qquad}\ ^\circ R}\right) = \underline{\qquad}\ \text{L}$$

Where: V_1 = Actual volume in L

P_2 = Standard Pressure = 406.8 in. H_2O

P_1 = Adjusted Pressure = (Plant Atmospheric Pressure (7460) of 314 in. H_2O) - (water vapor pressure) + (wet test manometer pressure - Note: suction is negative). P_1 = ________ - ________ ± ________ = ________in. H_2O

T_2 = Standard temperature (absolute) = 77°F + 459.6 = 536.6°R

T_1 = Actual Temperature (absolute) = ________°F + 459.6 = ________°R

Calculate ozone concentration.

$$\text{mg/L air} = (\underline{\qquad}\ \text{mg})\left(\frac{1}{\underline{\qquad}\ \text{L}}\right) = \underline{\qquad}\ \text{mg/L air}$$

$$\text{ppm/vol} = \left(\frac{\underline{\qquad}\ \text{mg}}{\text{L air}}\right)(1{,}000{,}000)\left(\frac{1}{1959}\right) = \underline{\qquad}\ \text{ppm/vol } (25^\circ C)$$

Ozone Supply:

Calculate ozonated air flow rate.

$$V_2 = V_1\left(\sqrt{\frac{P_1}{P_2}}\right)\left(\sqrt{\frac{T_2}{T_1}}\right)\left(\frac{T_3}{T_2}\right) = (\underline{\qquad}\ \text{cfm})\left(\sqrt{\frac{\underline{\qquad}\ \text{psia}}{20.7\ \text{psia}}}\right)\left(\sqrt{\frac{529.6^\circ R}{\underline{\qquad}\ ^\circ R}}\right)\left(\frac{536.6}{529.6}\right) = \underline{\qquad\qquad}\ \text{scfm } (25^\circ C)$$

Where: V_1 = Actual Volume in Ft^3

P_2 = Standard Pressure (absolute) = Gauge Pressure + Atmospheric Pressure = 6 psig + 14.7 psi = 20.7 psia

P_1 = Actual Pressure (absolute) ≐ Gauge Reading (psig) + Plant Atmospheric Pressure (7460) of 11.34 psi or Actual Atmospheric Pressure ________ in. H_2O x 0.036 psi/in. H_2O = ________psi
________psig + ________psi = ________psia

T_2 = Standard Temperature for Rotameter (absolute) = 70°F + 459.6 = 529.6°R

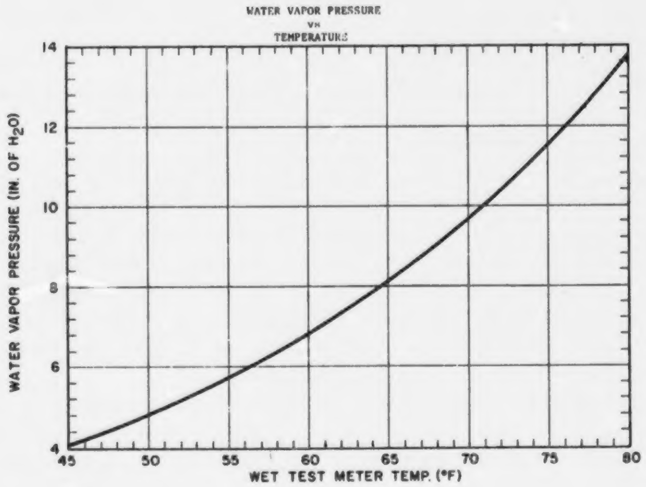
T_1 = Actual Temperature for Rotameter (absolute) = ________°F + 459.6 = ________°R

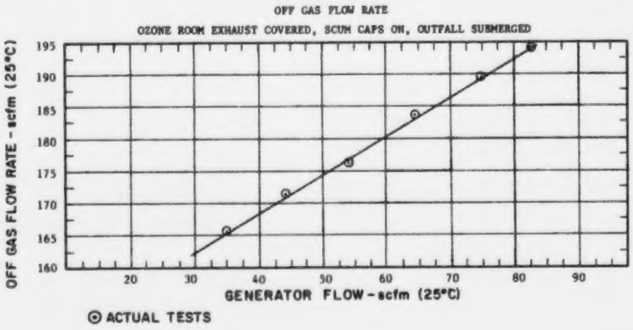
T_3 = Standard Temperature of 25°C (absolute) = 77°F + 459.6 = 536.6°R

(Continued)

TABLE H-2 (CONT). OZONE OFF-GAS DATA RECORDING SHEET

OZONE SYSTEM PERFORMANCE DATA


WATER VAPOR PRESSURE
vs
TEMPERATURE


OFF GAS FLOW RATE
OZONE ROOM EXHAUST COVERED, SCUM CAPS ON, OUTFALL SUBMERGED